AN ANALYSIS OF RESIDUARY DRAG

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by

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ABSTRACT

By a re-definition of the standard coefficients of form, wherein displacement is weighted by its distribution in depth, the analysis of wave making resistance is simplified. Using the Taylor Standard Series as a data base, regression analyses are employed to develop a universal wave drag function of only one variable for each speed length ratio.

Form drag is decomposed into components which facilitate analysis. Prediction formulae are developed graphically from the Taylor Standard Series data.

Using the prediction formulae developed, wave drag and form drag are predicted for a number of sample ships and are compared to that predicted by Gertler's reanalysis of the Taylor Standard Series. Similar comparisons are made for a half dozen models which are unlike the Taylor Standard Series parent with their individual towing tank test results. Differences and possible sources of error are discussed.

Thesis Supervisor: Jerome H. Milgram

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NOMENCLATURE

A	sectional area
A^*	sectional area weighted by its distribution in depth
A_m	midship section area
A_m^*	midship section area weighted by its distribution in depth
$A[\theta]$	free wave amplitude spectrum
B	beam at midship section
B/T	beam to draft ratio
C_B	block coefficient = ∇/LBT
C_f	form drag coefficient = $R_f/1/2\,\rho V^2 S$
C_o	skin friction error coefficient = $R_o/1/2\,\rho V^2 L^2$
C_1	coefficient of the form drag coefficient proportional to displacement = $R_1/1/2\,\rho V^2 L^2$
C_m	midship section coefficient = A_m/BT
C_m^*	midship section coefficient of the weighted sectional area = A_m^*/BT
C_p	longitudinal prismatic coefficient = $\nabla/A_x L$
C_p^*	weighted longitudinal prismatic coefficient = ∇^*/A^*L
C_x	midship section coefficient = A_x/BT
C_R	residuary resistance coefficient = $R_R/1/2\,\rho V^2 S$
$C_R(.5)$	residuary resistance coefficient at $V/\sqrt{L} = .5$
C_S	wetted surface coefficient = $S/\sqrt{\nabla L}$
C_V	volumetric coefficient = ∇/L^3
C_V^*	weighted volumetric coefficient = ∇^*/L^3
C_W	wave drag coefficient = $R_W/1/2\,\rho V^2 L^2$

∇	displaced volume
∇^*	displaced volume weighted by its distribution in depth
δ	boundary layer thickness
F	Froude number = $V/\sqrt{gL}$, where V is in feet per second
F_o	skin friction error function
F_1	form drag slope function
F_2	interim wave drag function = $(F_3)(1000)^{.2}$
F_3	universal wave drag function
g	gravitational constant = 32.2 ft/sec^2
K	wave number = $2\pi/\lambda = g/V^2$
L	length on the waterline
LCB	longitudinal center of buoyancy
LCB*	longitudinal center of the weighted displaced volume, ∇^*
L/T	length to draft ratio
λ	wave length
ϕ	velocity potential of a 2-D wave
ϕ_o	velocity potential of a 2-D wave at z=0
R_f	form drag
R_R	residuary resistance
R_w	wave drag
R_o	skin friction resistance error
R_1	form drag component proportional to displacement
S	wetted surface
T	draft at the midship section

θ	direction of propagation relative to ship heading
$V/\sqrt{L}$	speed length ratio (L in ft., V in kts.)
V	ship speed (in knots or ft. per second)
$y(x,z)$	offset of hull form
y_s	half width of separated wake

I. INTRODUCTION

Although many phenomena encountered in Naval Architecture have been reduced to relatively simple prediction formulae with reasonable engineering accuracy, there are as many which do not admit to any simple analysis. Among the most notorious are those phenomena which are responsible for the residuary resistance of ships. Withstanding centuries of scrutiny and data taking, they have steadfastly refused to collapse into any reasonably simple relationships involving the standard coefficients of ship hull form.

During the 18th century, Chapman [3] built ship model towing tanks and developed scaling laws and ship synthesis models from his observations. Unable to sort out all the phenomena involved in ship resistance with his ship model experiments and other observations, he complained, "For ships, we have to fear an infinity of bad qualities of the greatest consequence, which we are never sure of being able to remove, without understanding the theory."

During the last century since the publication of Froude's paper [13] in 1868, ship model basins have been constructed in many parts of the world for the purpose of measuring the residuary component of ship resistance.

Although we have probably sorted out most of the phenomena involved in ship resistance and have explained them with theories, we have not yet succeeded in predicting residuary drag

in terms of standard ship form coefficients. This is due not only to the mathematical complexity of the theory, but also to the quantities required to be measured by the theory which are in general not those measured by standard coefficients of ship hull form. The difficulty is best expressed by Weinblum [26]. "... the wave resistance depends, to a first approximation, upon a complicated function of the surface slope in the longitudinal direction, i.e., on derivatives. On the other hand, the most commonly used hull coefficients are integrals which, even when kept constant, still admit of very wide variations of the slopes. We realize now why the solution of the basic problem of the model basins mentioned above - to establish the resistance as a function of the form - remains almost hopeless as long as the ship surfaces (or at least their most important features) are not defined in a rigorous way by mathematical expressions."

It is the purpose of this thesis to do just that, i.e., to relate residuary drag to hull form. The success of this endeavor depends on two considerations. The first is that the description of the hull form adopted for the thesis contains parameters which measure the distribution of displacement in depth and its effect on the velocity potential with Froude number, in place of some of the standard coefficients of form. The second is the word "almost" in Weinblum's quote.

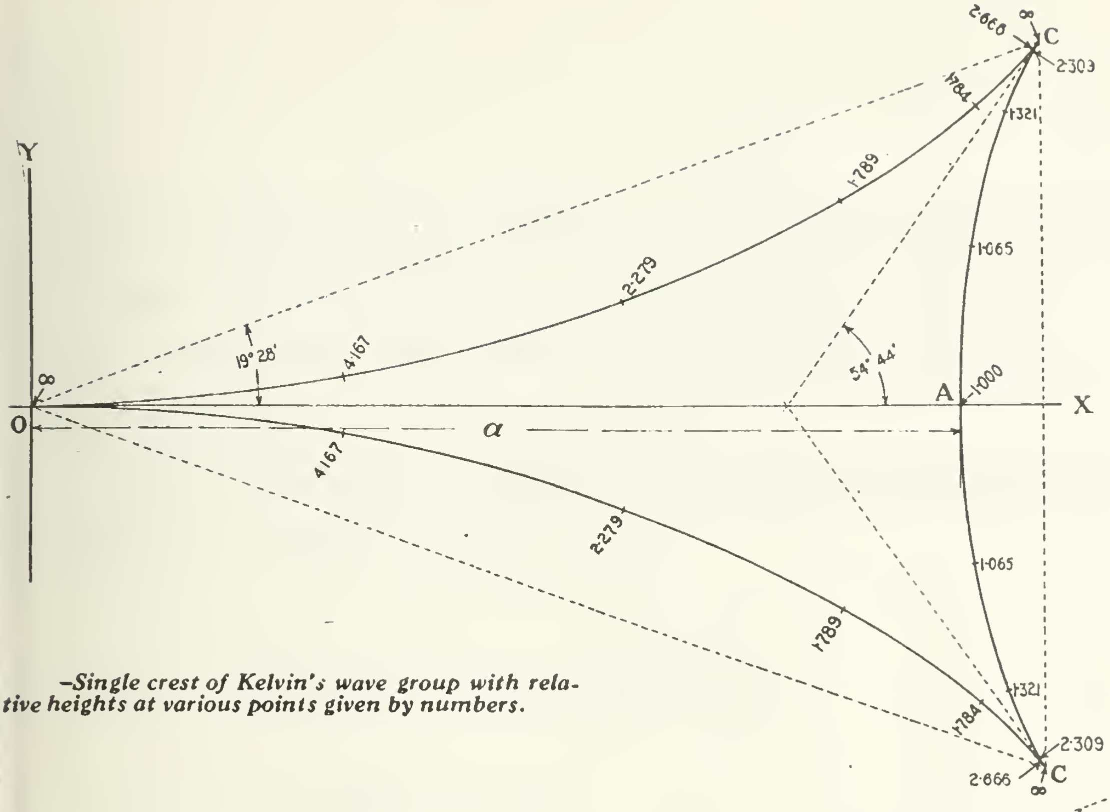
II. WAVE DRAG

The wave drag expressed in terms of the generated free wave amplitude spectrum, $A(\theta)$, will be:

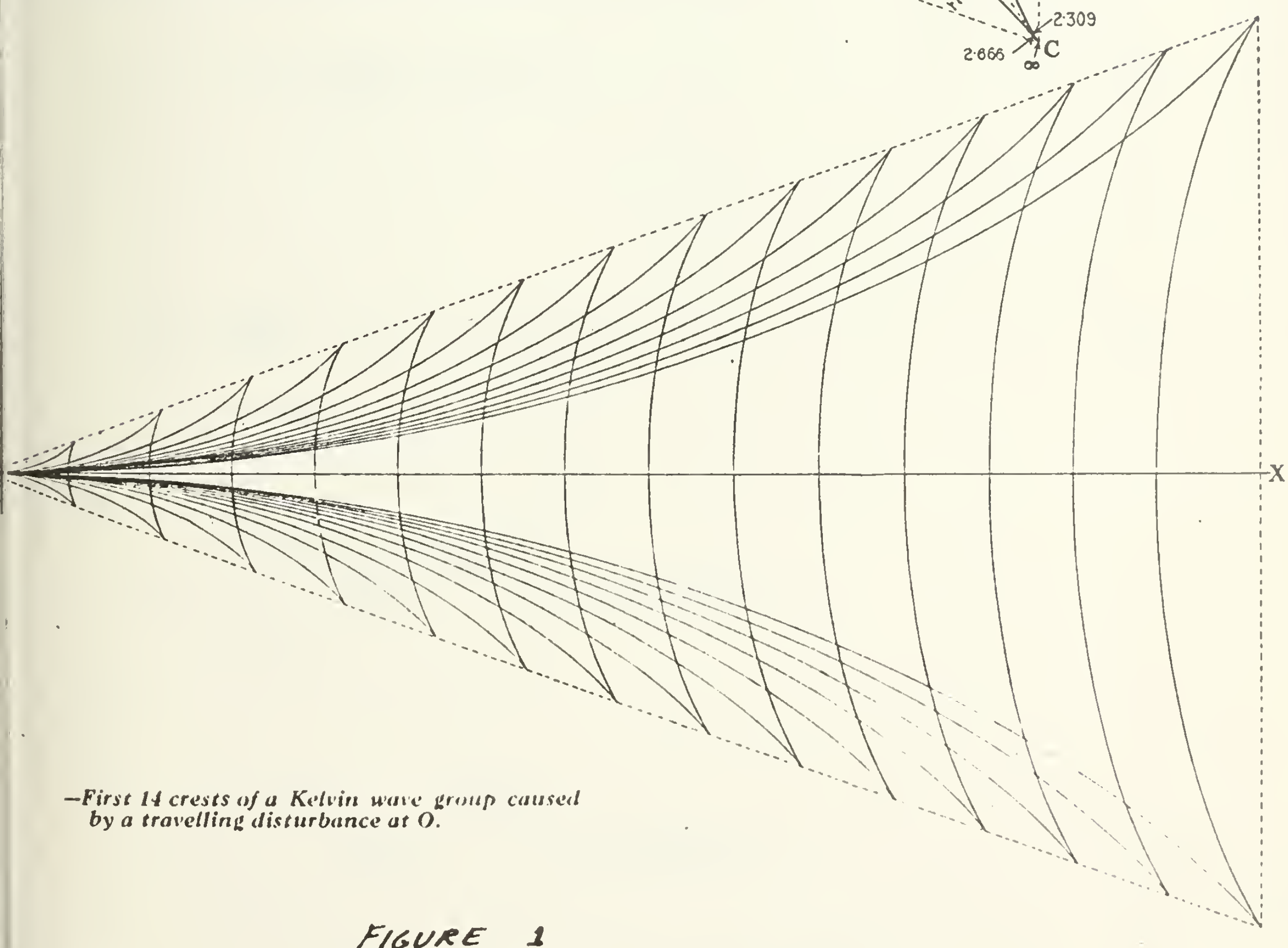
$$R_w = \frac{1}{2} \pi \rho V^2 \int_{-\pi/2}^{+\pi/2} [A(\theta)]^2 \cos^3\theta d\theta \qquad (1)$$

The $\cos^3\theta$ term represents the weighting of the contribution of each part of the wave spectrum to wave drag with the relative direction of propagation. The $\cos^3\theta$ weighting function indicates that the major contribution to wave drag will be from those waves travelling in the same direction as the ship ($\theta=0$). A Kelvin wave pattern is illustrated in Figure 1 (taken from reference 22) which shows ship generated waves propagating in various directions. In this illustration, it is the transverse waves following the ship which radiate most of the energy away from the ship. In view of the relatively small contribution to wave drag from the shorter diverging waves, it is a reasonable simplification to represent the wave system causing wave drag by the wave length and wave number of the predominate transverse wave.

Several analytical methods have been derived predicting the wave drag of slender bodies. Mitchell's [14] integral is probably the method most often cited. Rather than standard coefficients of form, Mitchell's integral measures the form of the hull in terms of longitudinal slopes of the surface of the



–Single crest of Kelvin's wave group with relative heights at various points given by numbers.



–First 14 crests of a Kelvin wave group caused by a travelling disturbance at O.

FIGURE 1

TAKEN FROM REFERENCE 22

hull at each point on the hull. The pressure change due to the resulting wave system is integrated over the ship to determine the total drag force. The coordinate system is shown in Figure 2.

Using Mitchell's integral, wave drag may be expressed as (taken from reference 26):

$$R = -2\iint \delta p \, dy \, dz = -2\iint dp \left(\frac{\partial y}{\partial x}\right) dxdz$$

$$= -2\rho V \iint \left(\frac{\partial \phi}{\partial x}\right)\left(\frac{\partial y}{\partial x}\right) dxdz \qquad (2)$$

or

$$R = \frac{4\rho g^2}{\pi V^2} \int_1^{\infty} (I^2 + J^2) \frac{\lambda^2}{\sqrt{\lambda^2 - 1}} \, d\lambda \qquad (3)$$

where

$$I = \int_{-e}^{+e} \int_0^{K(x)} \left(\frac{\partial y}{\partial x}\right) e^{-\frac{\lambda^2 gz}{V^2}} \cos\left(\frac{\lambda g x}{V^2}\right) dxdz$$

and

$$J = \int_{-e}^{+e} \int_0^{K(x)} \left(\frac{\partial y}{\partial x}\right) e^{-\frac{\lambda^2 gz}{V^2}} \sin\left(\frac{\lambda g x}{V^2}\right) dxdz$$

where $z = K(x)$ is the profile of the fairbody.

It may be seen from the foregoing that Mitchell's integral

COORDINATE SYSTEM:

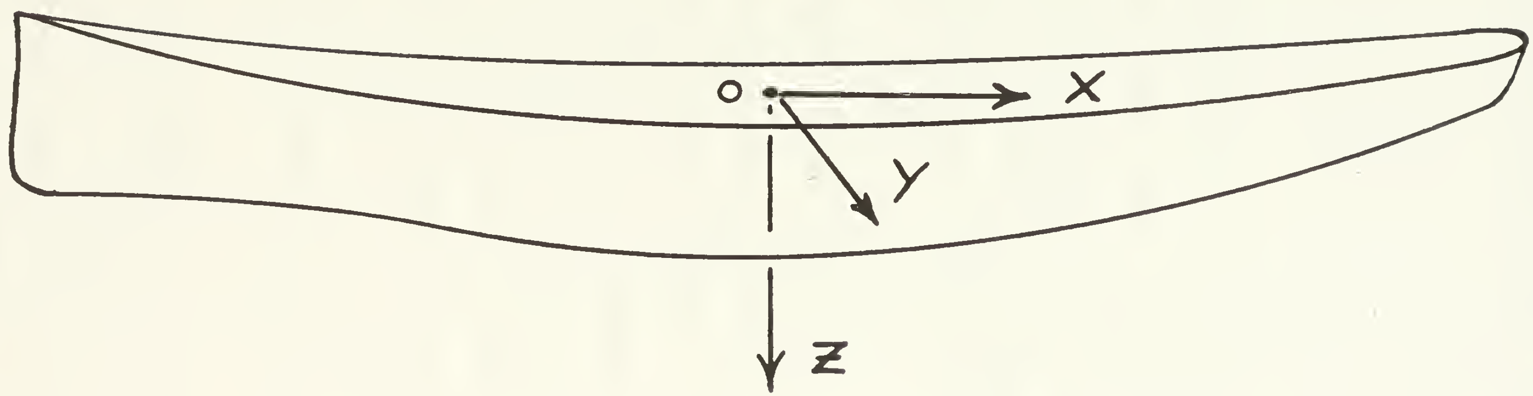


FIGURE 2

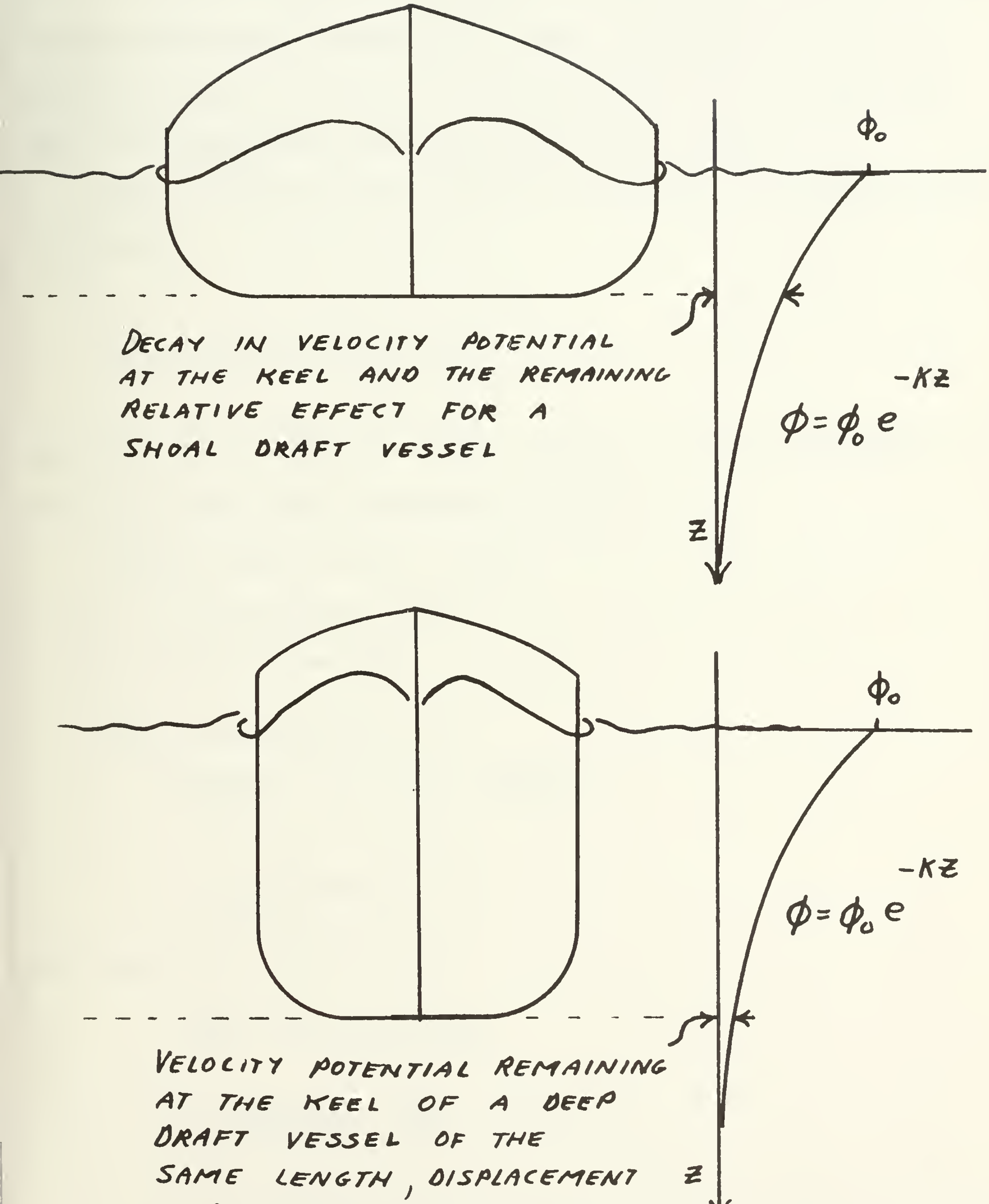
integrates the slope of a given waterline, $\frac{\partial y}{\partial x}$, weighted by a factor,

$$e^{-\frac{\lambda^2 gz}{V^2}} = e^{-\frac{\lambda^2}{F^2}} \qquad (4)$$

where $F = \frac{V}{\sqrt{gz}}$ is a local Froude number based on the ship speed and the depth of the waterline, over the length of the ship. The area of each waterline is then weighted by its speed and depth below the free surface. The weighted waterline areas are in turn integrated over the draft, which weights each increment of displacement by its depth.

The "effective" displacement of a ship which contributes to the wave making velocity potential is therefore something less than the real displacement by the weighting factor in Mitchell's integral. If the lines of two vessels of equal real displacement are similar except for proportional changes in beam to draft ratio, the smaller beam to draft ratio should have less effective displacement and less wave drag than the vessel with the larger beam to draft ratio. The difference in the effect of the displacement at various depths is illustrated in Figure 3.

In addition, due to the wave number, K, in the exponent, it is expected that the magnitude of any effect on wave drag due to the distribution of displacement in depth will also depend on speed length ratio or Froude number. For high speeds



ϕ_o
DECAY IN VELOCITY POTENTIAL AT THE KEEL AND THE REMAINING RELATIVE EFFECT FOR A SHOAL DRAFT VESSEL
$\phi = \phi_o e^{-KZ}$
Z
ϕ_o
$\phi = \phi_o e^{-KZ}$
VELOCITY POTENTIAL REMAINING AT THE KEEL OF A DEEP DRAFT VESSEL OF THE SAME LENGTH, DISPLACEMENT AND FROUDE NUMBER
Z

FIGURE 3

where the wave length of the ship generated waves is approaching the waterline length of the ship, the change in velocity potential over the draft of the ship will become relatively small for ships with large length to draft ratios.

The variation of the velocity potential with depth may be written as:

$$\phi(z) = \phi(z=0)e^{-Kz} = \phi_o e^{-Kz} \tag{5}$$

where the wave number, $K = \frac{g}{V^2} = \frac{2\pi}{\lambda}$ and λ is the wavelength of the transverse waves generated by the ship.

At high speed length ratios,

λ approaches L, and

K approaches $\frac{2\pi}{L}$.

The speed length ratio,

$$\frac{V(\text{knots})}{\sqrt{L}} \text{ approaches } \frac{V(\text{knots})}{\sqrt{\lambda}}$$

$$= \frac{V}{1.689\sqrt{2\pi V^2/g}} = 1.34$$

and the Froude number, F

$$= \frac{V}{\sqrt{gL}} \text{ approaches } \frac{V}{\sqrt{g\lambda}}$$

$$= \frac{V}{\sqrt{g(2\pi V^2/g)}} = \frac{1}{\sqrt{2\pi}} = .399$$

In addition, the effect on the velocity potential,

$$\phi_o e^{-Kz} \text{ approaches } \phi_o e^{-\frac{2\pi z}{L}}.$$

At this high speed, the effect on the velocity potential at various values of z is:

$$\phi(z=\tfrac{1}{4}) = \phi_o e^{-\pi/2} = .208\phi_o \qquad (6)$$

$$\phi(z=\tfrac{L}{9.065}) = \phi_o e^{-2\pi/9.065} = \tfrac{1}{2}\phi_o \qquad (7)$$

$$\phi(z=\tfrac{L}{50}) = \phi_o e^{-2\pi/50} = .882\phi_o \qquad (8)$$

The speed of a displacement vessel corresponding to a Froude number of $\frac{1}{\sqrt{2\pi}}$ is often referred to as the "hull speed" for that vessel. It may be seen from the foregoing calculations that the magnitude of the velocity potential will decay in depth from the free surface at a rate which will reduce its value to one half that at the surface at a depth of about one ninth of the waterline length of the vessel at hull speed.

As ship speed is decreased from a speed length ratio of 1.34, i.e., down from "hull speed", wave drag decreases sharply. The wave number, however, increases rapidly as speed is decreased, thereby increasing the rate of decay of the exponential with depth. There exists, therefore, a speed range wherein the wave drag has not yet become negligibly small, but where the rate of decay with depth of the velocity potential

has become very strong. In this situation the effect of the distribution of displacement in depth on the wave drag may become very important. Figure 4 illustrates the change in the decay profile of the velocity potential with ship speed.

The decay of the velocity potential with wave number and depth may be written:

$$\phi(z) = \phi_o e^{-Kz} = \phi_o e^{-gz/V^2} \tag{9}$$

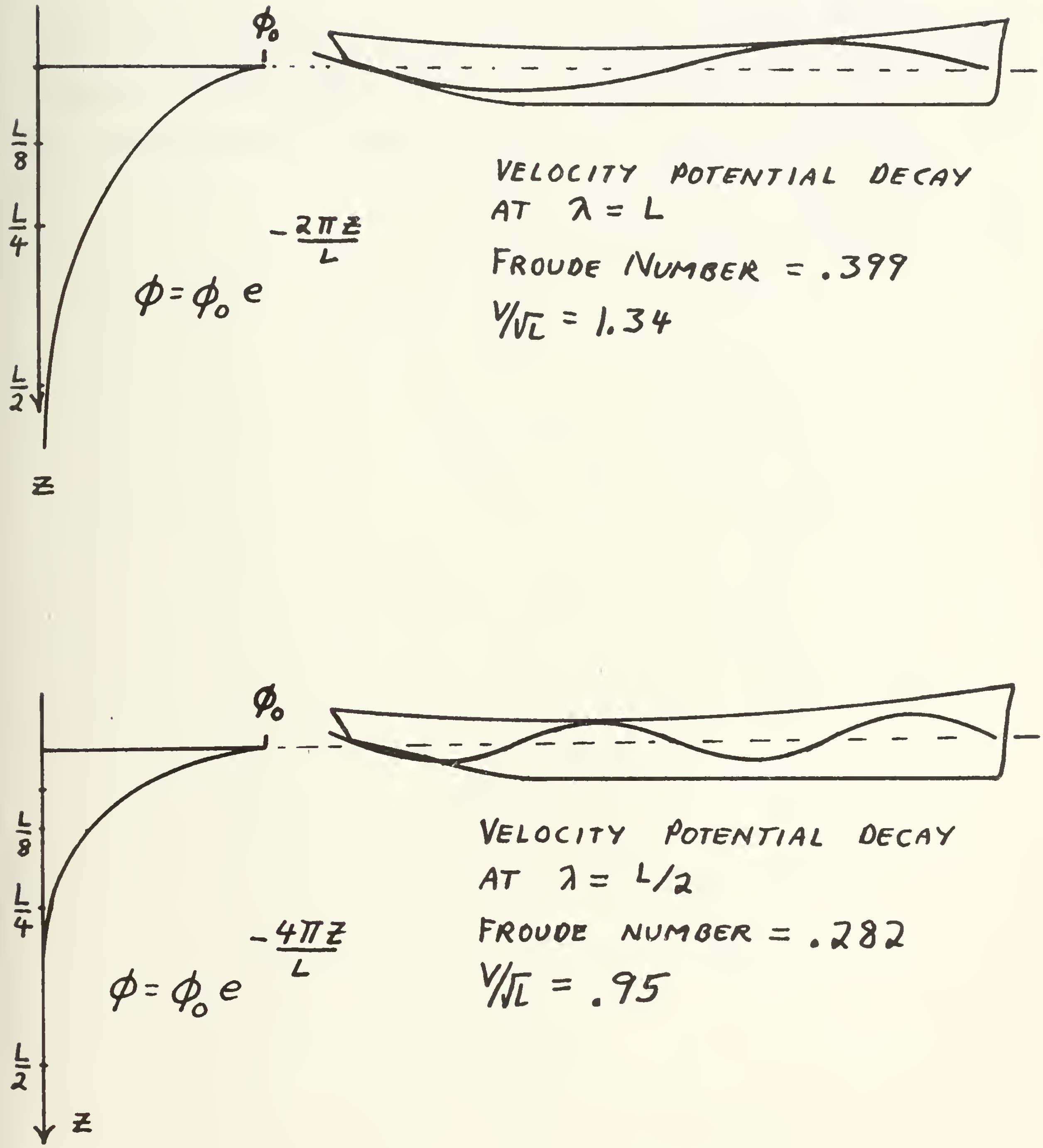
To demonstrate the variation in the decay curve of the effect of displacement with depth, caused by length draft ratio, we may look at the amount by which the effective displacement is reduced at the keel. Taking z=T,

$$\phi(z) = \phi_o e^{-gT/V^2} = \phi_o e^{-(gL/V^2)(T/L)}$$

$$= \phi_o e^{-1/(F^2)(L/T)} \tag{10}$$

where F is the Froude number and L/T is the length to draft ratio.

It may be seen from this approximation that a large length to draft ratio will flatten out the decay curve in a manner similar to that of a large Froude number. Long shallow ships or high speeds will therefore result in the least influence of the distribution of displacement over depth on wave drag. For



CHANGE IN THE DECAY OF VELOCITY POTENTIAL WITH SHIP SPEED.

FIGURE 4

either long shallow ships or high speeds, in other words, the effective displacement will approach the real displacement in its contribution to wave making.

III. FORM DRAG

Without viscosity, the water is allowed to slip past the hull of a ship, its interaction with the ship being limited to normal forces and wave radiation. D'Alembert's paradox allows the pressure distribution aft to produce the same normal forces as those acting against the forward part of the ship. With the introduction of even the smallest amount of viscosity, however, a no-slip condition is imposed upon the skin of the ship. This would directly result in the shearing of viscous layers of fluid very close to the hull and the diffusion of vorticity outward at a rate proportional to the gradient of velocity at the hull. In addition, at high Reynold's numbers, vorticity is physically convected away from the hull by turbulent mixing. By these mechanisms, momentum is exchanged with the flow and the velocity distribution is changed from that of the inviscid flow. For very high Reynold's numbers this region of high vorticity flux and momentum exchange is limited to a relatively thin boundary layer which grows from the bow to the stern and continues aft as all or part of the wake. Figure 5 shows the boundary layer thickness and velocity profiles along the hull of a ship. The presence of the flow entrained in the boundary layer prevents the streamlines aft from closing as quickly as those in the inviscid case. As a result, the pressure is not able to increase aft back up to the value which would produce

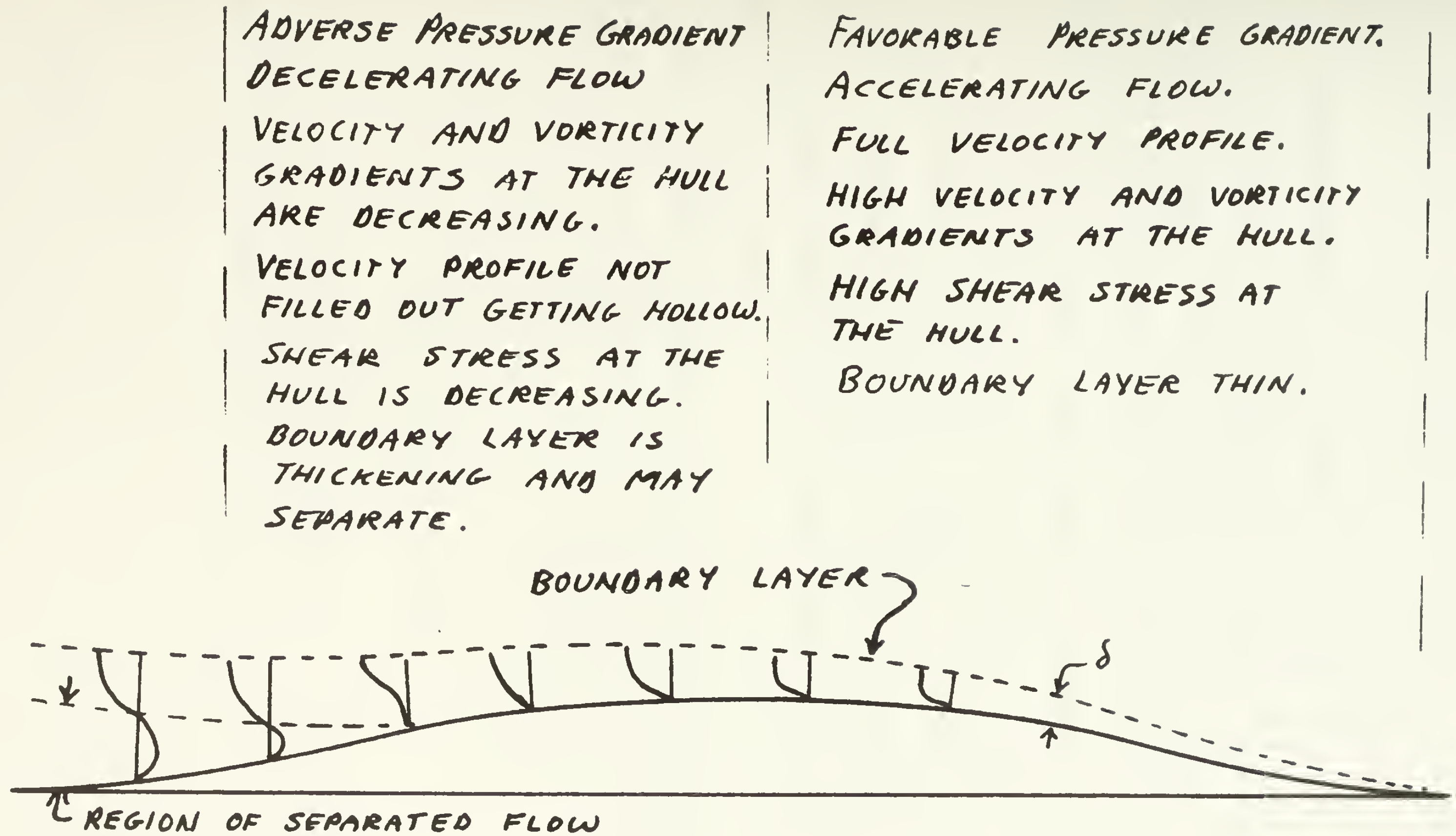

ADVERSE PRESSURE GRADIENT
DECELERATING FLOW
VELOCITY AND VORTICITY GRADIENTS AT THE HULL ARE DECREASING.
VELOCITY PROFILE NOT FILLED OUT GETTING HOLLOW.
SHEAR STRESS AT THE HULL IS DECREASING.
BOUNDARY LAYER IS THICKENING AND MAY SEPARATE.
FAVORABLE PRESSURE GRADIENT.
ACCELERATING FLOW.
FULL VELOCITY PROFILE.
HIGH VELOCITY AND VORTICITY GRADIENTS AT THE HULL.
HIGH SHEAR STRESS AT THE HULL.
BOUNDARY LAYER THIN.
BOUNDARY LAYER
δ
REGION OF SEPARATED FLOW

FIGURE 5

normal forces aft with forward components to equal the after components of the normal forces on the forward part of the ship. The difference in longitudinal components of the normal forces resulting from a reduction in the pressure field aft by the boundary layer is the viscous pressure drag.

If the curvature of the hull lines aft is too abrupt or if for any other reason the pressure gradient in the direction of flow is strongly adverse, the boundary layer flow may separate from the hull, leaving a region of reversed flow following the ship. The region of flow following the ship constitutes a momentum defect, which can be much larger than that due to the boundary layer itself.

Very roughly, drag due to flow separation may be represented in a two-dimensional velocity profile with the reference frame fixed on the ship, as shown in Figure 6.

$$D = \int_{-\infty}^{+\infty} \rho u (U_\infty - u) dy \simeq \int_{-\delta}^{+\delta} \rho u (U_\infty - u) dy \qquad (10a)$$

From Figure 3, it can be seen that for a separated wake, the contribution to this integral from separation along is approximately

$$\int_{-y_s}^{+y_s} \rho V^2 dy.$$

This quantity may be quite large. If flow separation

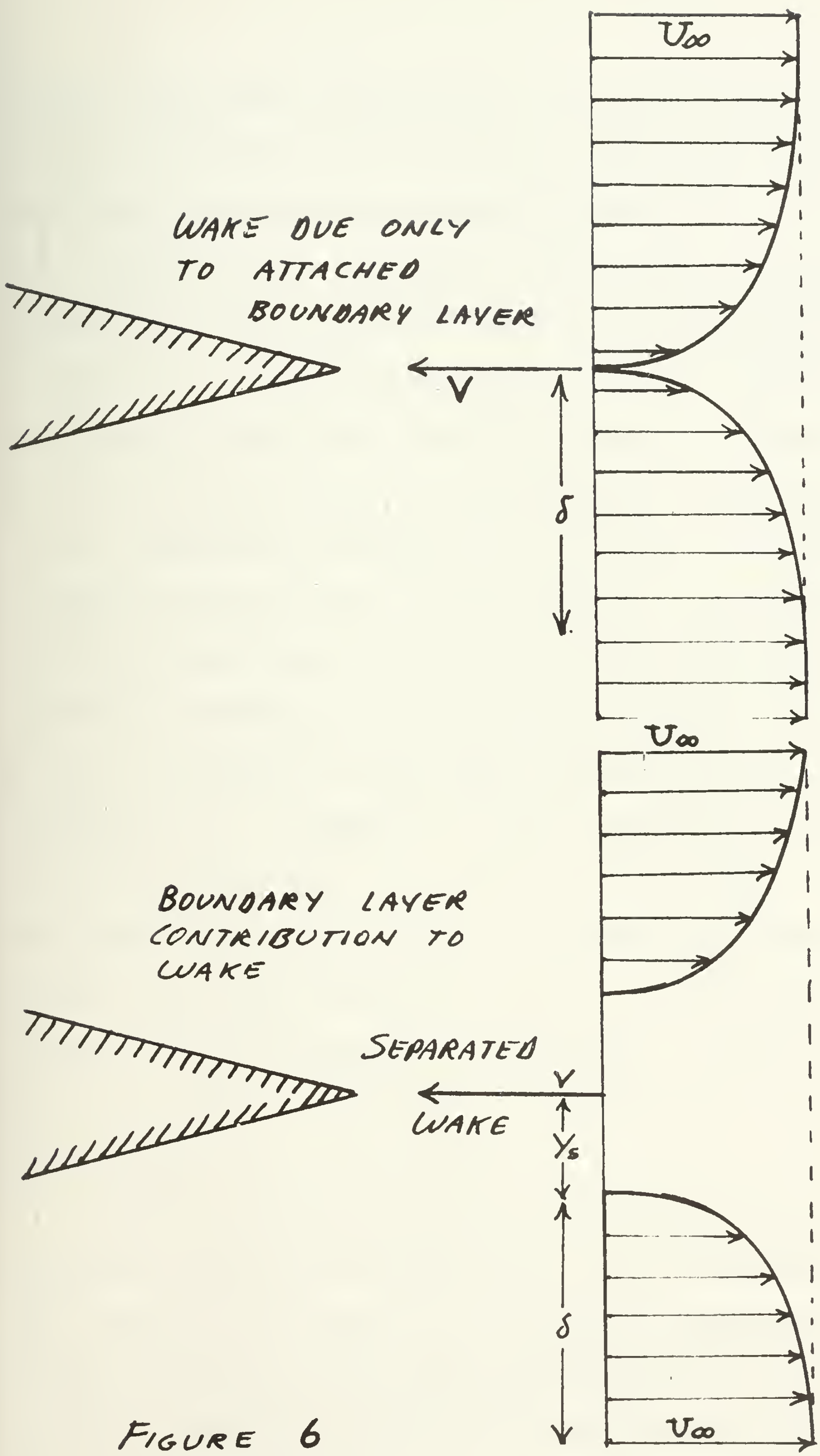

U_∞
WAKE DUE ONLY TO ATTACHED BOUNDARY LAYER
V
δ
U_∞
BOUNDARY LAYER CONTRIBUTION TO WAKE
SEPARATED WAKE
V
Y_s
δ
U_∞

FIGURE 6

occurs, then the form drag will increase by this large amount and may increase to a value many times that of the form drag due only to an attached boundary layer.

An additional component of drag which is related to the form of the hull is the difference in frictional resistance between the wetted surface of the ship in a plane uniform flow and that in the curved form of the hull. Because flow is forced around the ship in a curved path, the pressure distribution causes an increase in the velocity near midships and a decrease near the ends. The increase in velocity around the midship region has a greater effect on the frictional drag than the reduction in velocity at the ends. The result is an overall increase in frictional resistance over that of plane uniform flow. In addition to the velocity field changes, the path is longer along a curved hull than along a flat plate of the same area. These effects are both more pronounced for shapes with high volumetric coefficients than for very slender forms with low volumetric coefficients. Since this friction drag is related to the form of the hull, it is included in form drag.

If form drag were plotted as a function of volumetric coefficient and then extrapolated to zero volumetric coefficient, the value of the drag at the resulting intercept point, although included in form drag by conventional test procedures, cannot be due to the amount of displacement contained in the

hull form because the hull can have no thickness at a zero value of volumetric coefficient. Since frictional resistance is not measured directly in the towing tank, but is calculated by whatever frictional drag formula is adopted by the test procedure, then the value of the form drag at zero volumetric coefficient constitutes primarily the difference between the value predicted by the adopted friction formula and that actually contributing to total drag. Where they are significant, any other errors in the measurement, calculation, and scaling of frictional drag would also end up in this category.

IV. THE INTERACTION BETWEEN WAVEMAKING AND FORM DRAG

The thickness of the boundary layer is dependent on the pressure gradient along the path of the flow. The pressure in general increases up to the stem, decreases toward midships, increases up to the stern and decreases back to ambient in the wake. Flow is thereby decelerated ahead of the ship, accelerated from the stem to midships, decelerated from midships aft and accelerated slightly into the wake. The fluid entrained in the boundary layer is then flowing against the pressure gradient from the midship section aft. The boundary layer will therefore thicken at a greater rate aft than it will in the accelerating flow forward. The pressure decrease from the stem to midships is greater than the pressure recovery from midships to the stern. This causes the viscous pressure drag mentioned in the previous section. It has the somewhat redeeming virtue, however, that the adverse pressure gradient against which the fluid in the boundary layer must flow is decreased in a gentle and continuous manner from that which would exist with a complete recovery of the pressure at the stern.

All of the foregoing refers only to the pressure distribution which would exist without waves. When the pressure distribution of a wave system is superimposed upon the pressure distribution discussed in the previous paragraph, skepticism arises concerning the predictability of the interaction between

two completely different phenomena which are each in their own right relatively unpredictable.

One of the most insidious interactions lurking in the towing tank might be the initiation of flow separation by the pressure field of the wave system. If the flow were on the verge of separation near the stern of a model and if the model were then run at a speed corresponding to a hollow in the resistance curve, the crest of a transverse wave would be positioned at the stern, adding a pressure peak near the end of an already adverse pressure gradient, whereupon flow separation might occur. This sudden increase in drag might then fill in all or part of an anticipated hollow in the resistance curve. If the speed were then changed to that corresponding to a hump in the anticipated resistance curve, a transverse wave trough would be positioned near the stern, reducing the pressure and accelerating the flow toward the stern. Any region of previously separated flow might be partially or completely reattached, suddenly reducing the drag and removing all or part of the expected hump in the drag curve.

In addition to the effect of the wave system on flow separation, flow separation may in turn affect the wave system. Mr. P.N. Joubert, in his comments on reference 9, cites an example of what appeared to be a wave induced by flow separation on the 12 meter yacht "Valiant".

In this way, the resistance curve of a model test might

be drastically altered by an interaction effect. If the model were then scaled up to a full size ship, the very large Reynold's number might prevent flow separation even in the presence of the same wave profile as was modelled. The resistance of the full size vessel might then be entirely different from its model test.

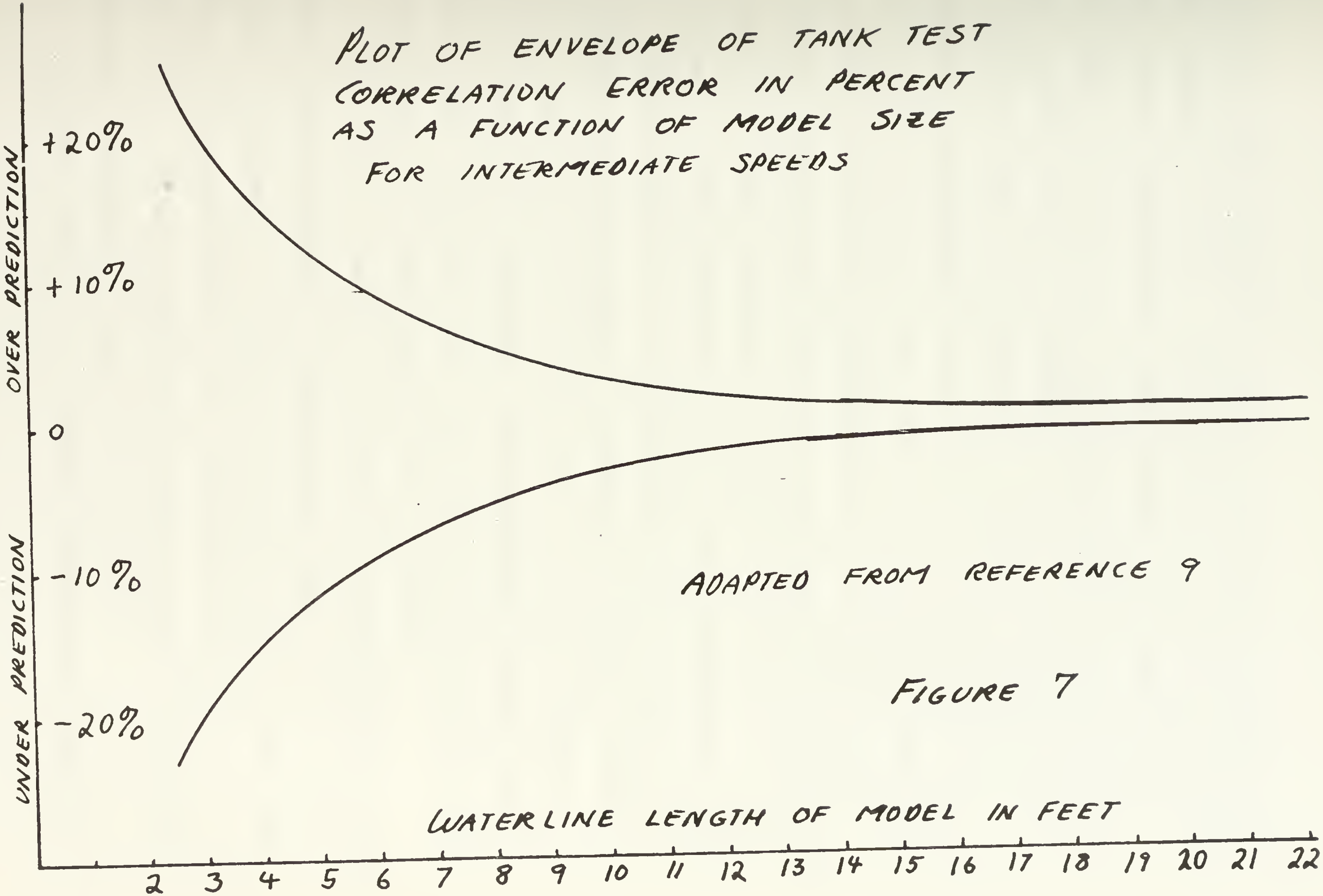
Even without flow separation, similar effects might be produced to a lesser degree simply by the influence of the wave system pressure field on the thickening and thinning of the boundary layer over the afterbody. R.L. Townsin [25] said that the reduction in the non-dimensional boundary layer thickness, δ/L, may be as great between an 8-foot model and a 28 foot model as it is between the 28-foot model and the full size ship. It is also agreed in the introduction to reference 25 that separation scale effects, if they exist, may appear over the range of model size.

V. THE DATA BASE

The selection of a methodical series of ship model tests for use as a data base for establishing trends and functional relationships between wave drag and other parameters is limited by several considerations. The first of these considerations is the absolute size of the model.

Regardless of the causes, the average magnitude of the errors encountered in tank test results increases strongly with decreasing model size and Reynold's number. Figure 7 shows this relationship. It is suspected by the author that irregularities in tank test data may result from the interactions between the wave system pressure field and the boundary layer along the afterbody, as discussed in the previous section. Uniformity in the behavior of the boundary layer is improved by increasing the Reynold's number and since the speed and kinematic viscosity are not available as control variables for this purpose, then increasing the size of the model will produce the same result. To insure that wave effects are measured in a flow regime similar to that of a full size ship, it is extremely important that any irregularities due to small model size be avoided. For this reason, all ship model test data for models less than 10 feet long were rejected as unreliable.

When one requires the size of the model to be larger than 10 feet, testing becomes extremely expensive and methodical



ADAPTED FROM REFERENCE 9

FIGURE 7

series for large models in recent years tend to include only small numbers of models. This brings us to the next consideration, that of statistical significance. Data populations with only a few variations in some parameters of interest may lead to results which, regardless of their correctness, will not stand up under any statistical measure of credibility. An example of this problem is provided by the BSRA Trawler Series (Part I) [17], wherein a total of only nine models were built. Four models with varying slenderness at a constant beam to draft ratio were tested along with five models of varying beam to draft ratio at a constant slenderness. With no variation in prismatic coefficient and so few in other parameters, Mr. G.S. Selman commented, "It surely needs a lot of imagination to produce from four models such wonderful curves, as shown.." [18]. Unless criticism of this nature is to be invited, a larger data base is required. This methodical series could not be used, therefore, even with a model size of twelve and a half feet and a scale ratio of only one 1/12.

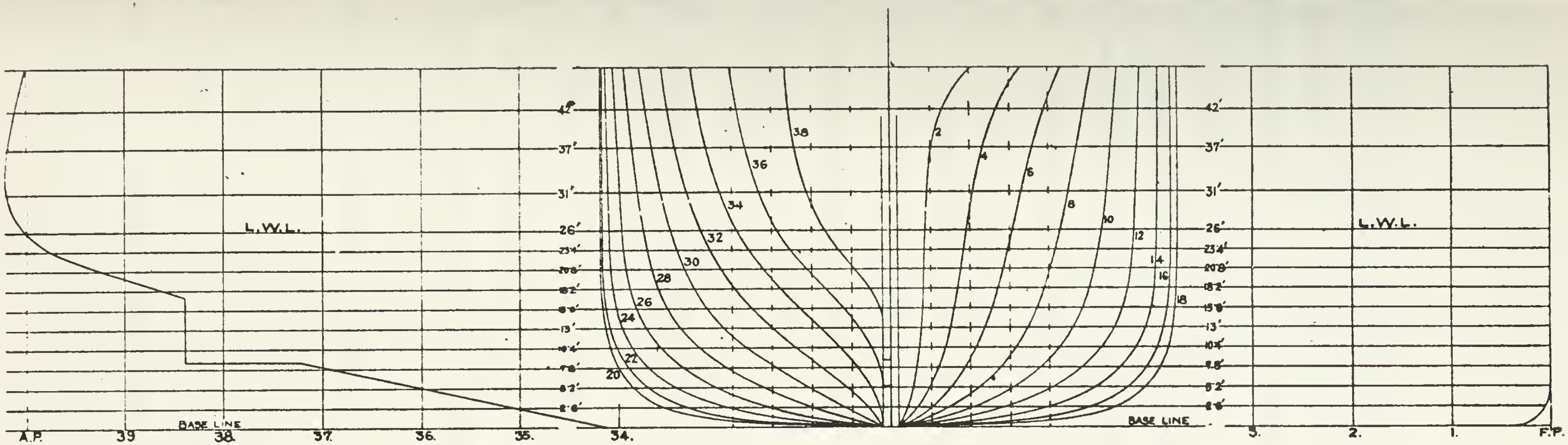
When other parameters are desired, the BSRA Trawler Series becomes more attractive. Although the number of data points in any one parameter is limited, changes in LCB, C_B and load condition are available if Part I and Part II [17 and 18] are both used. Valuable insights have been gained from multiple regression analysis of the entire series [17].

Series 60 [24] was investigated and even with large numbers

of large models, could not be used because the range of prismatic coefficient did not include values sufficiently low to be applied to many vessels other than merchant ships. In addition, the parent lines of Series 60 possess shoulders which, although appropriate for merchant ships, might introduce the additional complexities of the fore and aft shoulder wave systems similar to those of the double-wedge-shaped body investigated by Wigley [27].

After consideration of several other methodical series, the Taylor Standard Series [7 and 22] was selected for a number of reasons. The models are all about 20 feet long and average about a ton in displacement. The number of data points available in the variation of volumetric coefficient, prismatic coefficient and speed length ratio are sufficiently large to clearly represent functional relationships. The lines of the parent model for the Taylor Standard Series are presented in Figure 8. Both LCB location and midship section coefficient are held constant in the Taylor Standard Series.

An additional attraction to the Taylor Series as a data base is the manner in which the sectional area curve and the lines of the parent are changed to produce the desired variations in form coefficients. The sectional area curve is defined by a fifth order polynomial which is related directly to the prismatic coefficient and which is proportioned for the variations in the series in a smooth reproducible manner. The



–Body plan and stem and stern profiles for parent form of Standard Series.

FROM REFERENCE 22

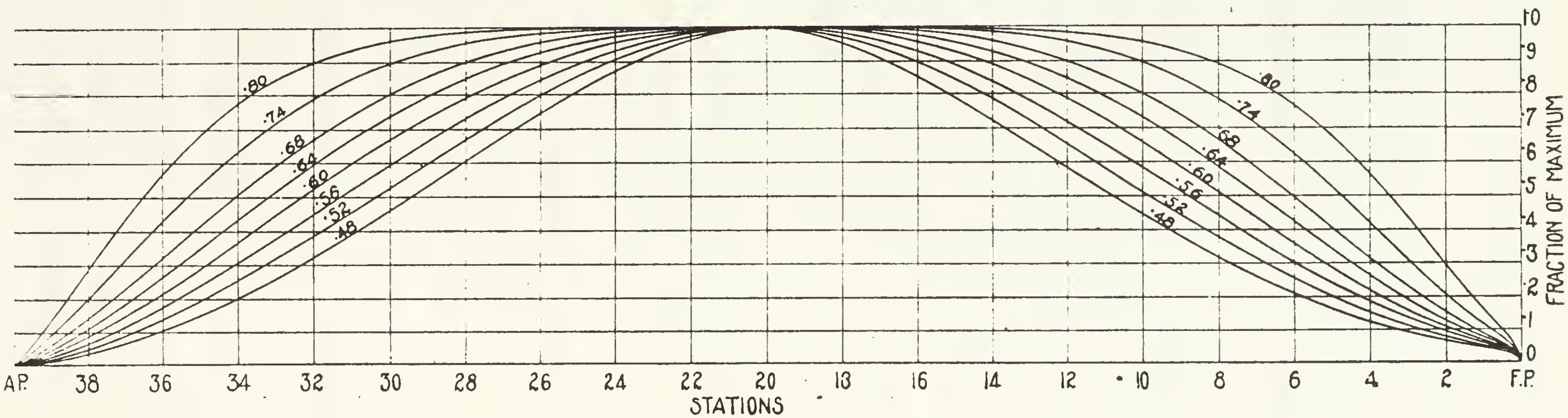


Figure 8 —*Relative curves of sectional areas for Standard Series. Each curve has noted on it the corresponding longitudinal coefficient.*

lines are changed from the parent graphically in a process consistent with the changes in the sectional area curve and produce very fair hull forms without shoulders or other areas of high local curvature.

Almost 200 models were tested from 1902 to 1914, of which 120 were published in The Speed and Power of Ships [22]. Almost 160 of these tests were later faired into the data presented in the Gertler re-analysis of the original test data [7]. Although the data is old, it is not out of date for the purposes of this thesis. In fact, a single methodical series of the magnitude of the Taylor Standard Series will probably never again be attempted.

The data published in the three editions of Taylor's The Speed and Power of Ships [22] included only beam to draft ratios of 2.25 (Series 21) and 3.75 (Series 22) between which interpolation was recommended. Series 20 contained the data for the intermediate value of beam to draft ratio of 2.92. Although Series 20 was completed prior to Series 21 and 22, it was, for some reason unknown to this author, not published along with Series 21 and 22 as an intermediate value from which to interpolate beam to draft ratio effects. In addition, Series 20 was not extended in 1913 and 1914 as were Series 21 and 22. Taylor did not explain why this data from some 38 models was left out, but only mentions in passing that it confirmed to some extent the validity of linear interpolation between Series

21 and 22.

"A Reanalysis of the Original Test Data for the Taylor Standard Series" [7] was published in 1954 by Morton Gertler. Series 20 was included in these data and was used to fair the data and provide an intermediate value of beam to draft ratio of 3.0. The original Taylor data was corrected for many effects and updated for modern conventions in this reanalysis. For this reason, the data presented in Gertler's reanalysis were used in this thesis with only one reservation. The behavior of the curves of residuary drag coefficient with that value at $V/\sqrt{L}$ = .5 subtracted out and then multiplied by the wetted surface plotted against volumetric coefficient for each beam to draft ratio, speed length ratio and prismatic coefficient reveal a very unusual behavior for the curve representing the beam to draft ratio of 3.0. While the curves for the B/T of 2.25 and 3.75 behave similarly, the curve for the B/T of 3.0 usually starts out shooting above the other two and then crossing over the other two at a higher value of volumetric coefficient. This strange behavior of the data for B/T of 3.0 is evident at many values of prismatic coefficient and speed length ratio when plotted carefully on a large scale. Examples are plotted in Figures 9, 10 and 11. Because of this unusual and unexplainable behavior, the data for B/T = 3.0 is not used in this thesis. It is possible that a difference in the behavior between the data for Series 20 and that of Series 21

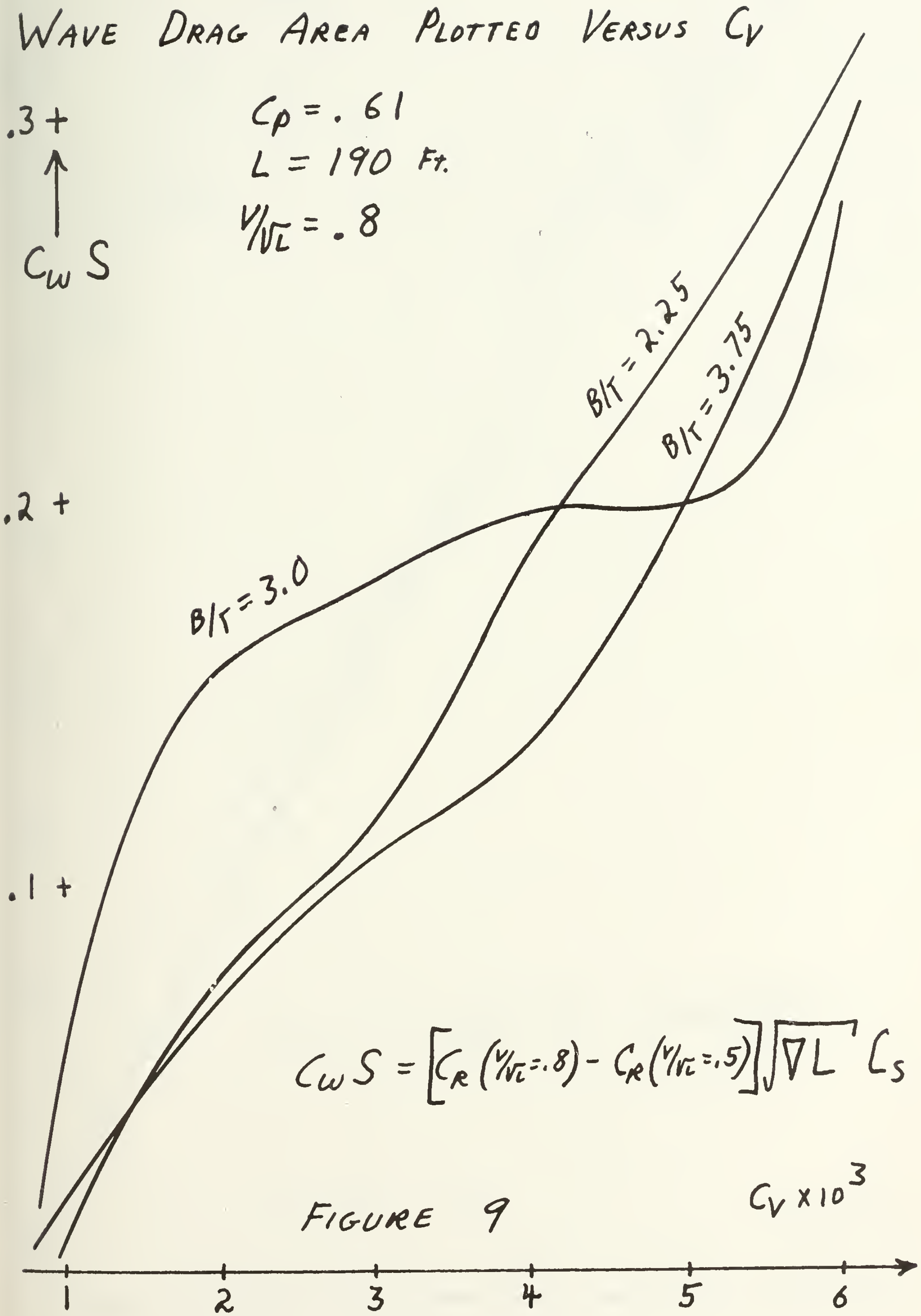

Wave Drag Area Plotted Versus C_V
$C_p = .61$
$L = 190$ Ft.
$V/\sqrt{L} = .8$
.3
.2
.1
$C_w S$
$B/T = 2.25$
$B/T = 3.75$
$B/T = 3.0$
$C_w S = \left[C_R\left(V/\sqrt{L}=.8\right) - C_R\left(V/\sqrt{L}=.5\right)\right]\sqrt{\nabla L}\; C_s$
$C_V \times 10^3$
1
2
3
4
5
6

FIGURE 9

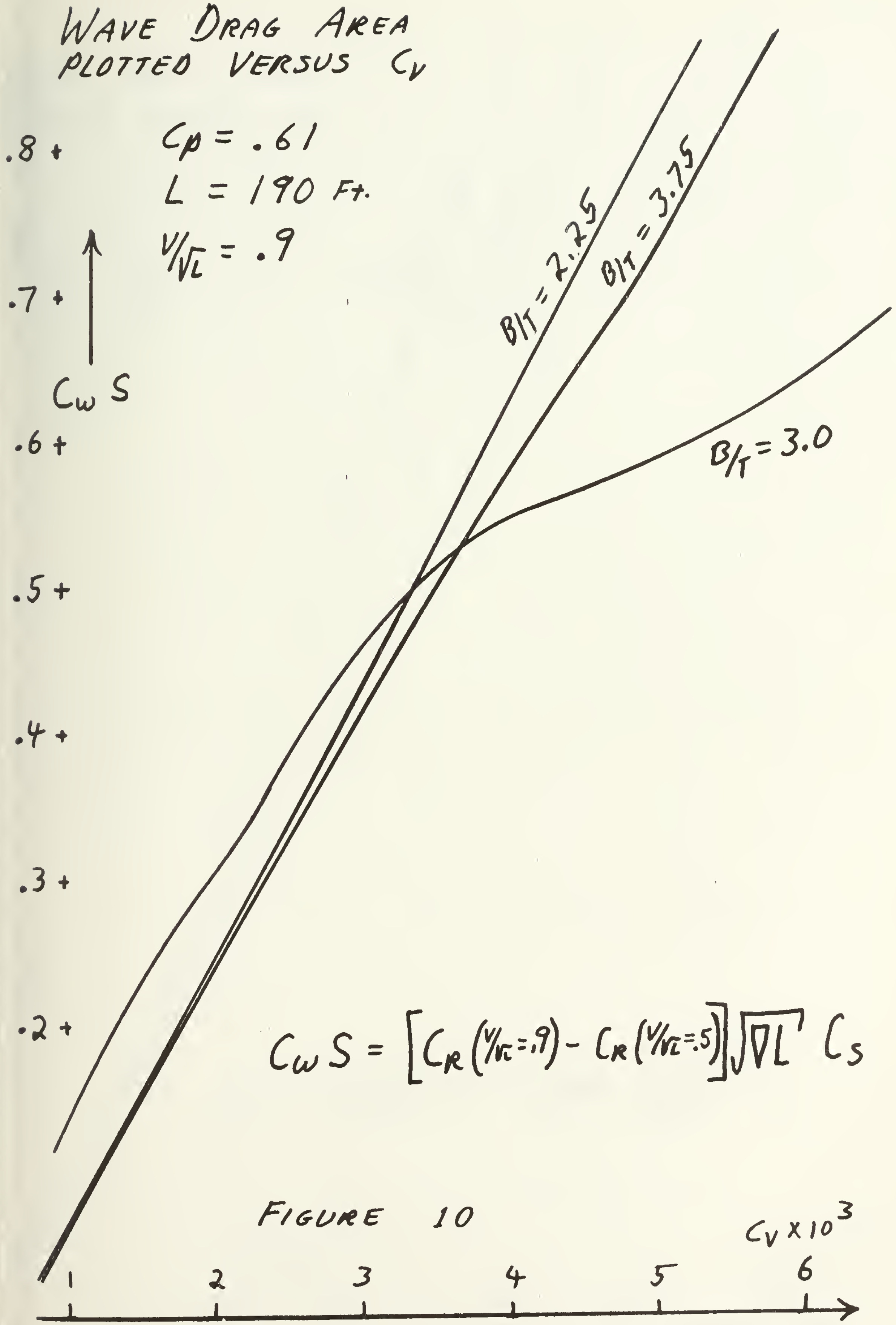

WAVE DRAG AREA
PLOTTED VERSUS C_V
$C_p = .61$
$L = 190$ Ft.
$V/\sqrt{L} = .9$
$C_w S$
.8
.7
.6
.5
.4
.3
.2
B/T = 2.25
B/T = 3.75
B/T = 3.0
$C_w S = \left[C_R(V/\sqrt{L}=.9) - C_R(V/\sqrt{L}=.5)\right]\sqrt{\nabla L}\; C_S$
$C_V \times 10^3$
1
2
3
4
5
6

FIGURE 10

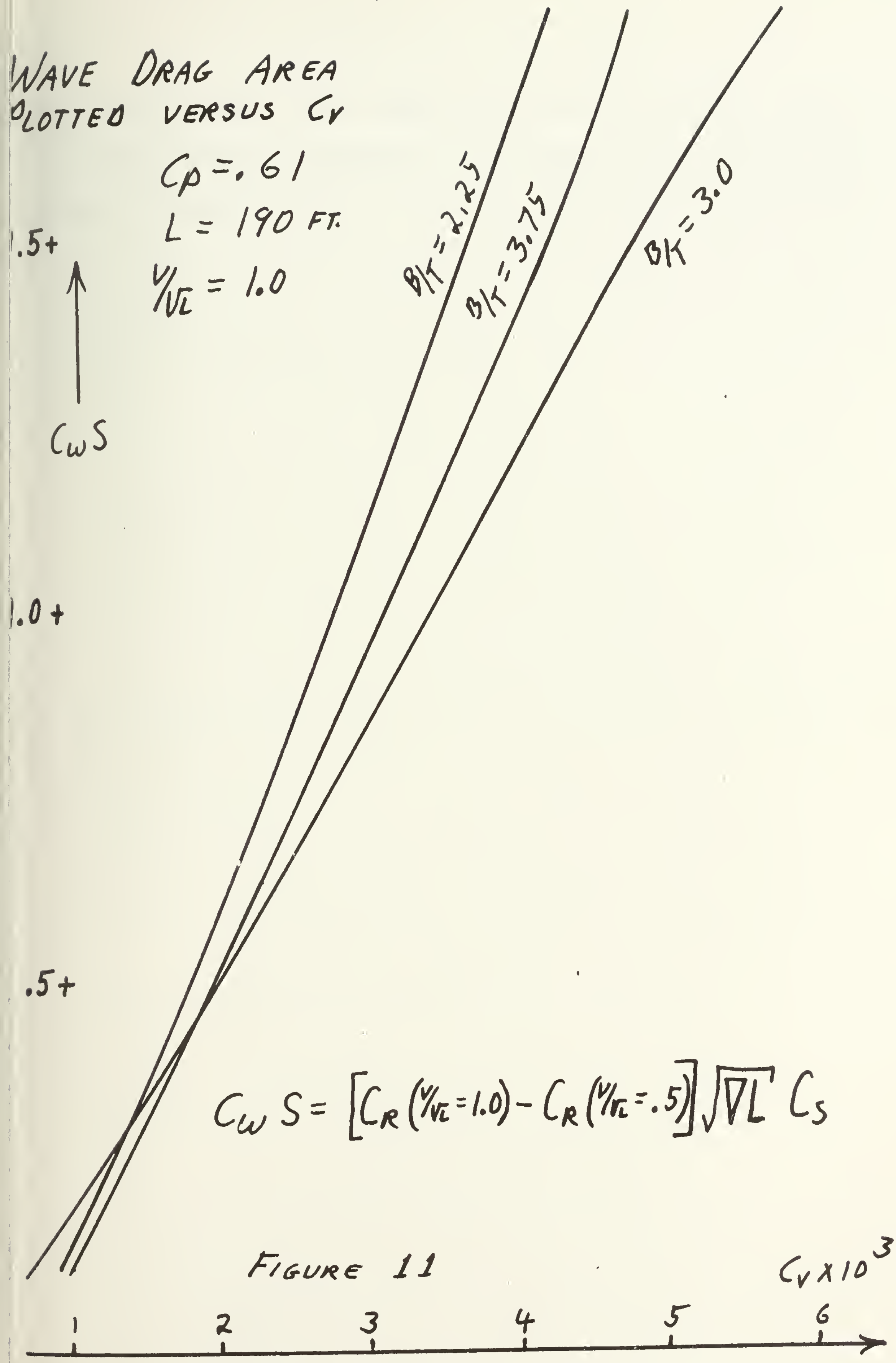

WAVE DRAG AREA
PLOTTED VERSUS C_V
$C_P = .61$
$L = 190$ FT.
$V/\sqrt{L} = 1.0$
1.5+
1.0+
.5+
$C_W S$
B/T = 2.25
B/T = 3.75
B/T = 3.0
$C_W S = \left[C_R(V/\sqrt{L} = 1.0) - C_R(V/\sqrt{L} = .5)\right]\sqrt{\nabla L}\, C_S$
$C_V \times 10^3$
1
2
3
4
5
6

FIGURE 11

and 22 may reflect some important problem with the models or the tests that was suspected or recognized by Admiral Taylor himself and was for that reason omitted from his publications.

VI. WAVE DRAG IN THE DATA BASE

Since the Gertler reanalysis of the Taylor Standard Series was chcsen as a data base, the range of length to draft ratio for which data was obtained will be examined to estimate the magnitude of the effect of the distribution of displacement in depth for reasonable wave numbers and speed length ratios.

$$LBT\ C_pC_m = \nabla \tag{11}$$

$C_m \approx .923$ for all Taylor Series models

$$\frac{BT}{L^2} = \frac{\nabla}{L^3}\,\frac{1}{C_pC_m} = \frac{C_v}{C_pC_m} \tag{12}$$

$$L^2 = \left(\frac{C_pC_m}{C_v}\right) BT \tag{13}$$

$$\left(\frac{L}{T}\right)^2 = \left(\frac{C_pC_m}{C_v}\right)\left(\frac{B}{T}\right) \tag{14}$$

$$\left(\frac{L}{T}\right) = \sqrt{\left(\frac{C_pC_m}{C_v}\right)\left(\frac{B}{T}\right)} \tag{15}$$

$$\left(\frac{L}{T}\right)_{max} = \sqrt{\frac{(.7)(.923)}{(.001)}\ (3.75)} = 49.2 \tag{16}$$

$$\left(\frac{L}{T}\right)_{min} = \sqrt{\frac{(.48)(.923)}{(.006)}(2.25)} = 12.9 \tag{17}$$

The variation in the velocity potential decay rate seen by

this data base is then

$$\phi((\frac{L}{T})_{max}) = \phi_o e^{-1/(F^2)(L/T)} = \phi_o e^{-1/49.2F^2} \tag{18}$$

$$\phi((\frac{L}{T})_{min}) = \phi_o e^{-1/(F^2)(L/T)} = \phi_o e^{-1/12.9F^2} \tag{19}$$

Since speed length ratios from 0.5 to 1.2 were included in the data base, the variation of the effects of the length to beam ratios included in the data base on the wave drag will be estimated. Froude number is proportional to the speed length ratio as follows:

$$F = \frac{V}{\sqrt{gL}} = \frac{1.689V_K}{\sqrt{g}\sqrt{L}} = (\frac{1.689}{\sqrt{g}})\frac{V_K}{\sqrt{L}} = .2976\frac{V_K}{\sqrt{L}} \tag{20}$$

At a $V_K/\sqrt{L} = 1.2$, Froude number is .357. Then,

$$\phi((\frac{L}{T})_{max}, \frac{V}{\sqrt{L}} = 1.2) = \phi_o e^{-1/(.357)^2(49.2)} = .853\phi_o \tag{21}$$

$$\phi((\frac{L}{T})_{min}, \frac{V}{\sqrt{L}} = 1.2) = \phi_o e^{-1/(.357)^2(12.9)} = .544\phi_o \tag{22}$$

It may be seen that at this speed length ratio, there is very little variation over depth of the velocity potential for the larger length to draft ratio. For the smaller length to draft ratio, however, the velocity potential is almost reduced in half at the draft of the ship. A given redistribution in

depth of sectional area or displacement would then presumably cause a larger change in wave drag for the smaller length to beam ratio than for the larger.

At a speed length ratio of 1.0, the Froude number is:

$$F = (.2976)\frac{V_K}{\sqrt{L}} = .2976 \tag{23}$$

Then,

$$\phi((\tfrac{L}{T})_{max}, \frac{V}{\sqrt{L}} = 1.0) = \phi_o e^{-1/(.2976)^2(49.2)} = .795\phi_o \tag{24}$$

$$\phi((\tfrac{L}{T})_{min}, \frac{V}{\sqrt{L}} = 1.0) = \phi_o e^{-1/(.2976)^2(12.9)} = .319\phi_o \tag{25}$$

Again it may be seen that the variation of $\phi(z)$ is quite large for the smaller length to draft ratio. The variation of $\phi(z)$ for the larger length to draft ratio, although greater at this speed, is still not a large fraction of ϕ_o.

At a speed length ratio of .8,

$$F = (.2976)\frac{V_K}{\sqrt{L}} = .2381 \tag{26}$$

and

$$\phi((\tfrac{L}{T})_{max}, \frac{V}{\sqrt{L}} = .8) = \phi_o e^{-1/(.2381)^2(49.2)} = .699\phi_o \tag{27}$$

$$\phi\left(\left(\frac{L}{T}\right)_{min}, \frac{V}{\sqrt{L}} = .8\right) = \phi_o e^{-1/(.2381)^2(12.9)} = .255\phi_o \quad (28)$$

At this speed length ratio, the variation of $\phi(z)$ is large even for the large length to draft ratio. At the same time, however, wave drag has decreased to a small value such that the absolute change in wave drag due to a given redistribution in displacement in depth would probably not be very large.

VII. HYPOTHESIS

It is hypothesized that the residuary drag may be decomposed into three components: wave drag, form drag and skin friction error.

$$R_R = R_o + R_1 + R_w \tag{29}$$

where R_w = wave drag = $\frac{1}{2}\rho V^2 L^2 C_w$

C_w = wave drag coefficient based on waterline length

R_1 = form drag = $\frac{1}{2}\rho V^2 L^2 C_1$

C_1 = form drag coefficient based on length

R_o = skin friction error = $\frac{1}{2}\rho V^2 L^2 C_o$

C_o = skin friction error coefficient based on length

It is further hypothesized that the wave drag will be a power law function of the displacement, ∇^*, of the ship weighted by its distribution in depth and an unknown function, F_3, of the longitudinal prismatic coefficient of the weighted displacement and the speed length ratio.

$$R_w = \frac{1}{2}\rho V^2 L^2 C_w \tag{30}$$

$$C_w = \left[\left(\frac{\nabla^*}{L^3}\right)^n\right]\left[F_3\left(C_p^*, \frac{V}{\sqrt{L}}\right)\right] \tag{31}$$

where n = exponent to be determined

F_3 = unknown function to be determined

Because it was expected that n would be approximately 2.0, a preliminary function was defined such that:

$$C_w = [(\frac{\nabla^*}{L^3})^2][F_2(C_p^*, \frac{V}{\sqrt{L}})] \tag{32}$$

F_2 could then be more easily determined and F_3 could be related back to F_2 when n became known more precisely.

$$C_w = F_3(\frac{\nabla^*}{L^3})^n = F_2(\frac{\nabla^*}{L^3})^2 \tag{33}$$

So,

$$F_3 = F_2(\frac{\nabla^*}{L^3})^{(2-n)} \tag{34}$$

In addition, it is expected that the form drag will be proportional to the real displacement, ∇, and also proportional to some unknown function, F_1, of the beam to draft ratio and the real (unweighted) longitudinal prismatic coefficient.

$$R_1 = \frac{1}{2}\rho V^2 L^2 C_1 \tag{35}$$

$$C_1 = [\frac{\nabla}{L^3}][F_1(\frac{B}{T}, C_p] \tag{36}$$

The skin friction error is defined as the value of the form drag when it is extrapolated to zero volumetric coefficient. It is defined in such a way that it represents that part of the form drag which cannot depend on the volumetric coefficient of the hull form. It would seem at first glance that since the hull form can have no volume to shape, the skin friction error should not depend on any form coefficient whatsoever. The other form coefficients are not, however, forced by the definition of skin friction error to be zero and it is expected that some of the errors included within the definition may vary with beam to draft ratio and prismatic coefficient. In addition, since the real skin friction is a function of the hull form, the skin friction error will in general also be a function of hull form as follows:

$$R_o = \frac{1}{2}\rho V^2 L^2 C_o \tag{37}$$

$$C_o = F_o(\frac{B}{T}, C_p) \tag{38}$$

VIII. DEFINITION OF NEW VARIABLES

Because the variation of the velocity potential of the wave system over depth depends upon both the Froude number and the depth itself, new variables must be defined which relate this dependency to the speed and form of the ship. In order to include the effect of the vertical distribution of displacement on the velocity potential with ship speed, a new displacement parameter is defined which is an integral over draft with the integrand weighted by depth and Froude number.

The area of each section may be weighted as follows:

$$\overset{*}{A}(x) = \int_{z=0}^{z=T} y(z,x)e^{-gz/V^2}dz \tag{39}$$

The weighted displacement is then:

$$\nabla^* = \int_{x=0}^{x=L} \overset{*}{A}(x)dx \tag{40}$$

$$\nabla^* \equiv \int_{x=0}^{x=L} [\int_{z=0}^{z=T} y(z,x)e^{-g/V^2\ z}dz]dx \tag{41}$$

where y(z,x) are the offsets determined graphically from reference 7, and $e^{-g/V^2\ z}$ represents the weighting factor for the contribution of the local displaced volume to the disturbance of the velocity potential.

It may be seen that, in general,

$$\nabla^{*} < \nabla \tag{42}$$

and that for high speeds, ∇^{*} approaches the real displacement. As discussed in the section on wave drag and the data base, all of the displaced volume contributes approximately the same toward the disturbance of the free surface at very high speeds.

In a manner similar to the derivation of standard coefficients of form, a new set of weighted coefficients may be derived which include in them their relative contributions to the disturbance of the velocity potential.

Define a weighted midship section area,

$$A_m^{*} = \int_{z=0}^{z=T} y(z)e^{-gz/V^2}dz = A^{*}(x) \text{ at } x = ⊗ \tag{43}$$

Then a weighted longitudinal prismatic coefficient may be defined:

$$C_p^{*} = \frac{\nabla^{*}}{A_m^{*}L} \tag{44}$$

The weighted volumetric coefficient would be written,

$$C_v^{*} = \frac{\nabla^{*}}{L^3} \tag{45}$$

The longitudinal center of weighted buoyancy is:

$$LCB^* \int_{x=0}^{x=L} x\, \overset{*}{A}(x)dx \Big/ \int_{x=0}^{x=L} \overset{*}{A}(x)dx = \frac{1}{\nabla^*} \int_{x=0}^{x=L} x\, \overset{*}{A}(x)dx \qquad (46)$$

Although a variation in LCB was not desired and LCB is fixed amidships in the Taylor Standard Series, LCB* will, in general, change with speed. The Taylor Series ships tend to have U-shaped sections forward and V-shaped sections aft. At low speeds, more ∇^* will be lost forward than aft and will result in a migration of LCB* aft at low speeds. To insure that this variation remained small enough to ignore, LCB* was defined and calculated.

IX. DATA REDUCTION

Within the data base of the Taylor Standard Series, a representative subset was chosen with enough data points to clearly establish trends between parameters. The subset of ships contains 70 ships with the following range of variation of coefficients of form:

$\frac{B}{T}$: 2.25, 3.75

CV: .001, .002, .003, .004, .005, .006, .007

C_p: .48, .54, .60, .65, .70

Fractional offsets were determined graphically for each variation of C_p for 10 stations and the 0, .1, .2, .3, .4, .5, .6, .8 and 1.0 waterlines.

For those residuary drag curves in reference 7 which are flat at the speed length ratio of .5, the residuary drag coefficient at this speed, $C_R(.5)$, is assumed to be essentially form drag. The form drag coefficient, C_1, based on length squared, may then be written as:

$$C_1 \equiv \frac{R_1}{1/2\,\rho V^2 L^2} \tag{47}$$

In reference 7, the wetted surface coefficient is defined as:

$$C_S \equiv \frac{S}{\sqrt{\nabla L}} \tag{48}$$

and

$$C_v \equiv \frac{\nabla}{L^3} \tag{49}$$

so that the combination of coefficients

$$C_R(.5)C_S\sqrt{C_v} = \left(\frac{R_R(.5)}{1/2\ \rho V^2 S}\right)\left(\frac{S}{\sqrt{\nabla L}}\right)\left(\frac{\nabla}{L^3}\right) = \frac{R_R(.5)}{1/2\ \rho V^2 L^2} = C_1 \tag{50}$$

is equal to the form drag coefficient, C_1.

The form drag coefficient, C_1, was then plotted against C_v for various values of C_p and B/T. The form drag coefficient was found to be essentially linear in C_v and was rewritten in the form

$$C_1 = F_1 C_v \tag{51}$$

where F_1 is simply the slope of the curve of form drag coefficient as a function of C_v. F_1 is, however, an unknown function of C_p and B/T. The form drag is then

$$R_1 = \tfrac{1}{2}\rho V^2 L^2 C_v F_1 (C_p, \tfrac{B}{T}) \tag{52}$$

The intercept of the curve of form drag coefficient versus

C_v extrapolated to C_v=0 is taken as the skin friction error coefficient based on length. So,

$$F_o = C_{R_o} C_S \sqrt{C_v} = \frac{R_o}{1/2\,\rho V^2 L^2} = C_o \tag{53}$$

where F_o is not a function of C_v, but is an unknown function of C_p and B/T.

The skin friction error is then,

$$R_o = \frac{1}{2}\rho V^2 L^2 F_o(C_p, \frac{B}{T}) \tag{54}$$

Examples of the plots of form drag coefficient versus C_v are provided in Figures 12, 13 and 14. Examples of plots of the form drag coefficient versus C_p are provided in Figures 15, 16 and 17. Although these plots include data for the beam to draft ratio of 3.0, these data were not used in the derivation of form drag functions.

Linear regression analyses were done graphically to determine reasonable fits for the functions $F_1(C_p, B/T)$ and $F_o(C_p, B/T)$. The following relationships were chosen:

$$F_o = .0027 + (C_p - .5)[.021 + (\frac{B}{T} - 2.25)(.02033)] \tag{55}$$

$$F_1 = 14 + (\frac{B}{T} - 2.25)[4 + 20.7(C_p - .5)] \tag{56}$$

Plots of F_o versus C_p are provided for three values of B/T in Figure 18.

Plots of F_1 versus C_p are also provided for three values of B/T in Figure 19 with some data points included.

PLOT OF FORM DRAG AS A FUNCTION OF VOLUMETRIC COEFFICIENT FOR VARIOUS VALUES OF PRISMATIC COEFFICIENT

F_1 = SLOPE

F_0 = INTERCEPT

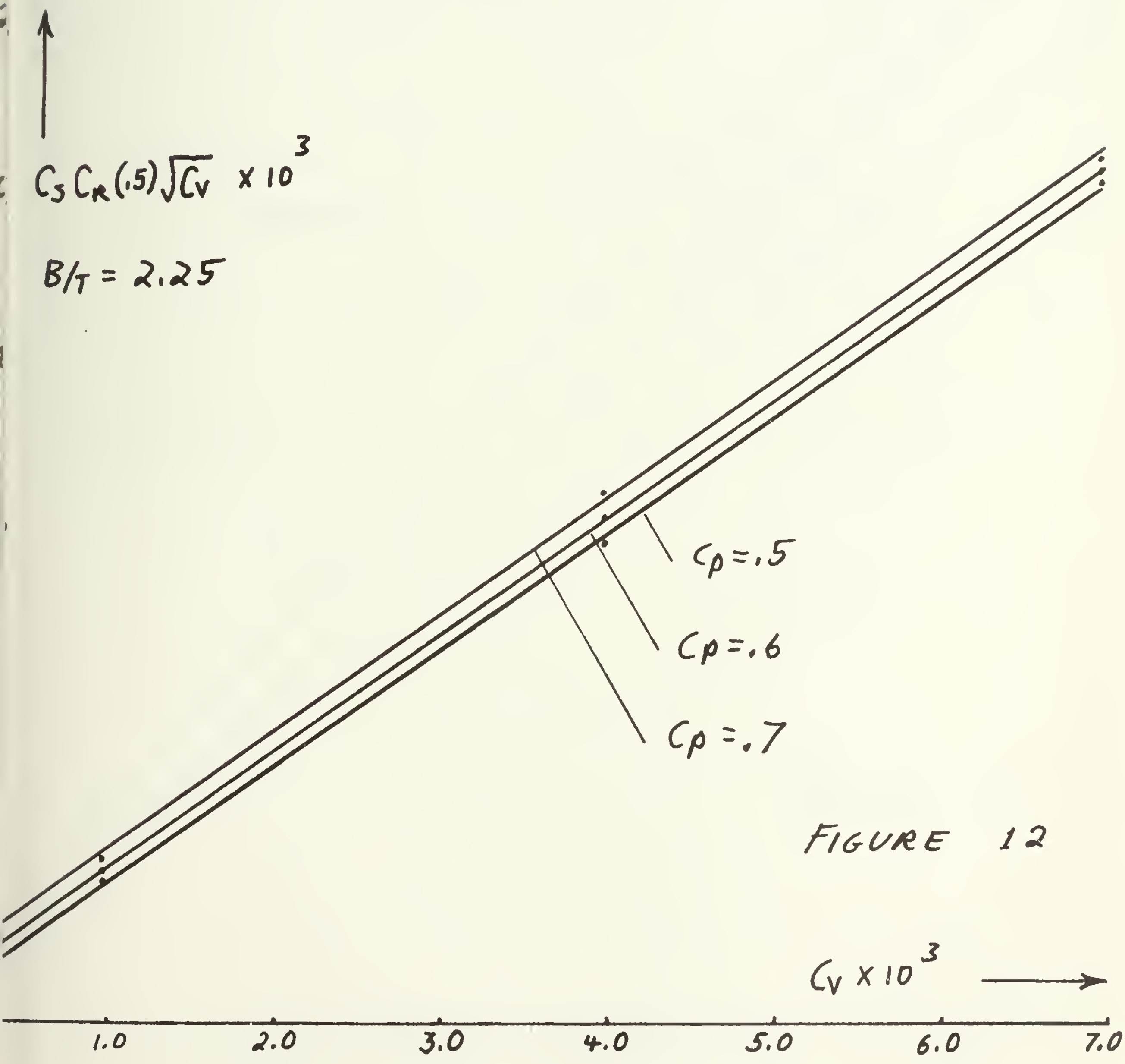


FIGURE 12

PLOT OF FORM DRAG AS A FUNCTION OF VOLUMETRIC COEFFICIENT FOR VARIOUS VALUES OF PRISMATIC COEFFICIENT

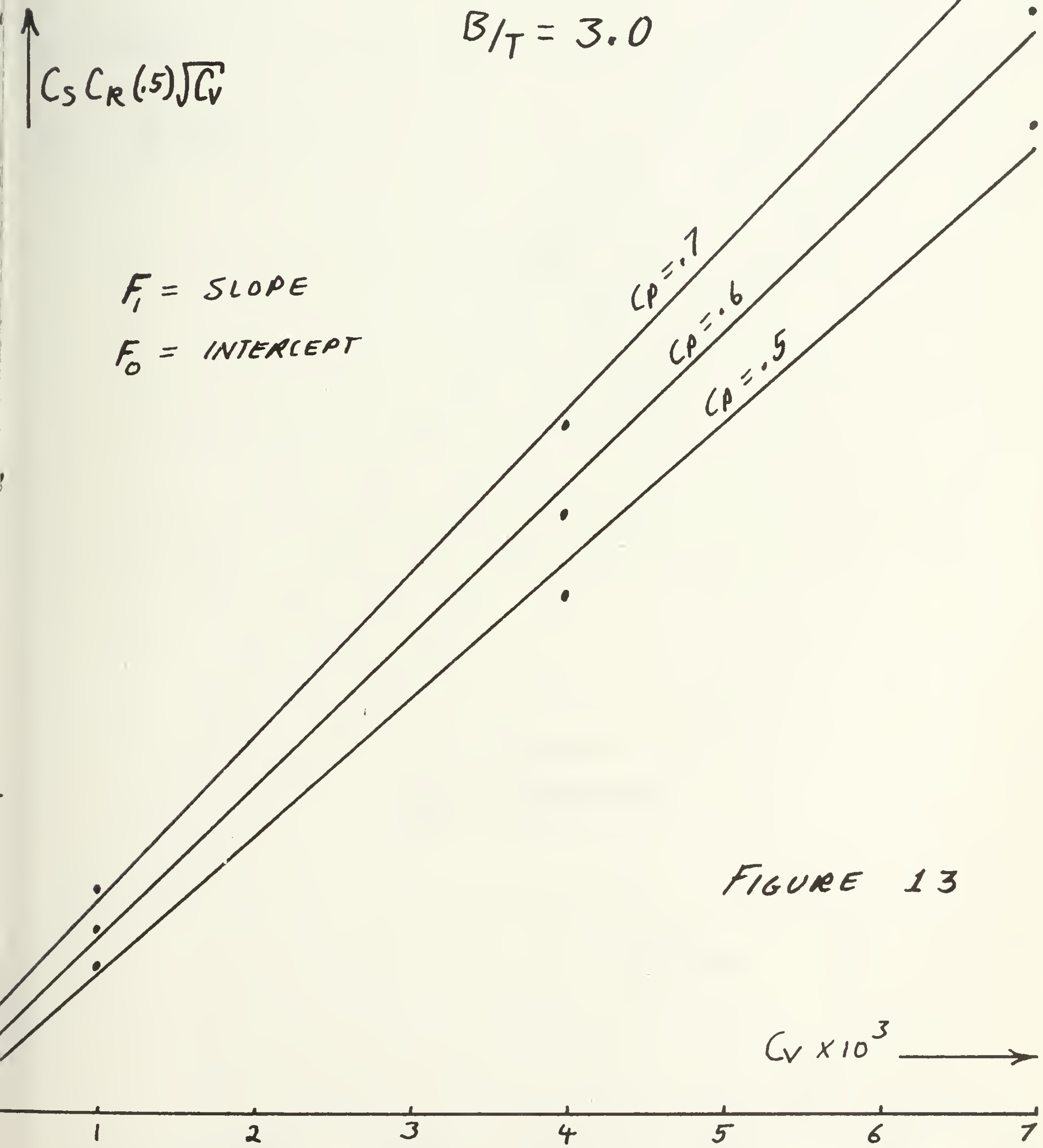


FIGURE 13

PLOT OF FORM DRAG AS A FUNCTION OF VOLUMETRIC COEFFICIENT FOR VARIOUS VALUES OF PRISMATIC COEFFICIENT

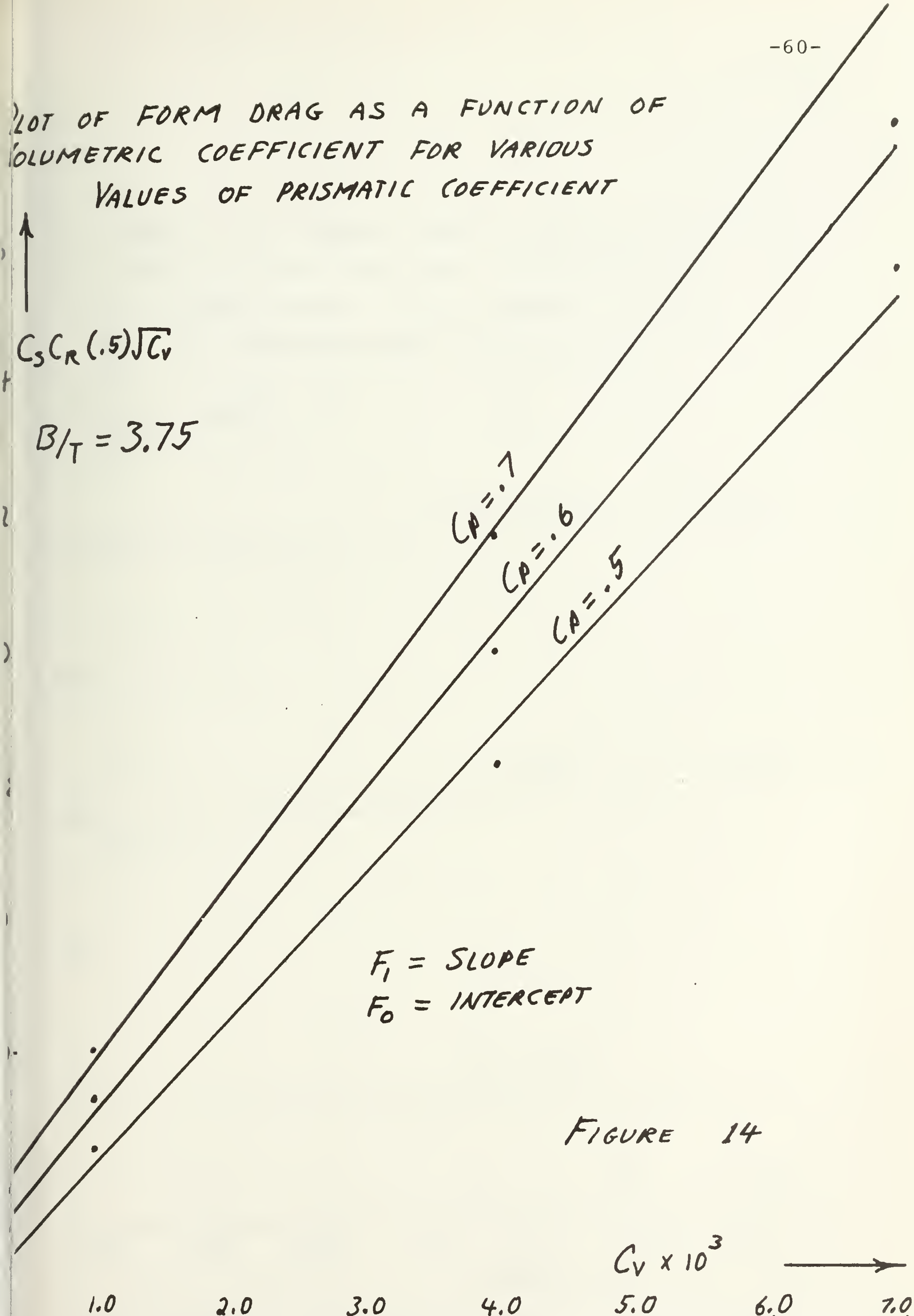


FIGURE 14

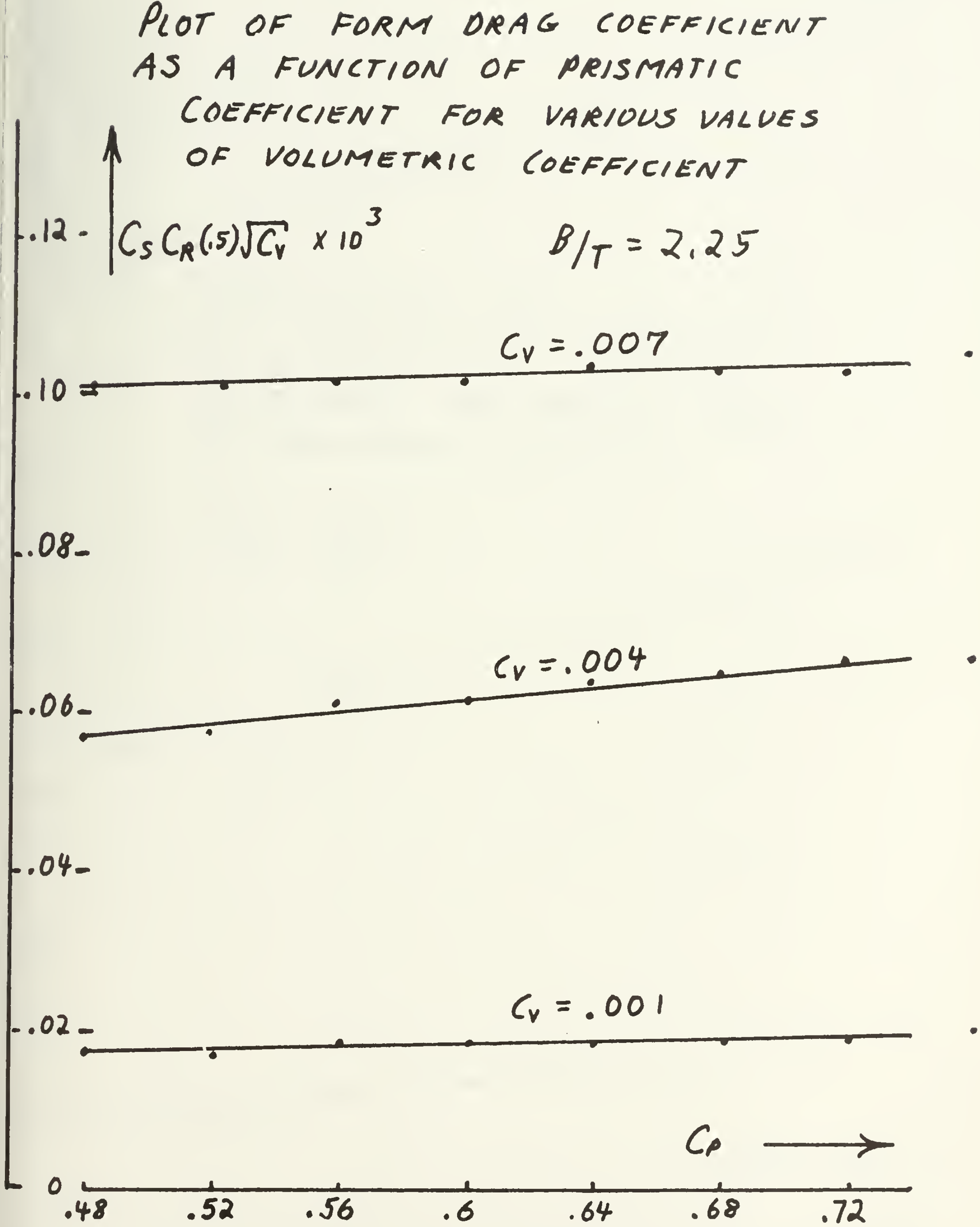

PLOT OF FORM DRAG COEFFICIENT AS A FUNCTION OF PRISMATIC COEFFICIENT FOR VARIOUS VALUES OF VOLUMETRIC COEFFICIENT
$C_S C_R(.5)\sqrt{C_V} \times 10^3$
$B/T = 2.25$
$C_V = .007$
$C_V = .004$
$C_V = .001$
C_P
.12
.10
.08
.06
.04
.02
0
.48
.52
.56
.6
.64
.68
.72

FIGURE 15

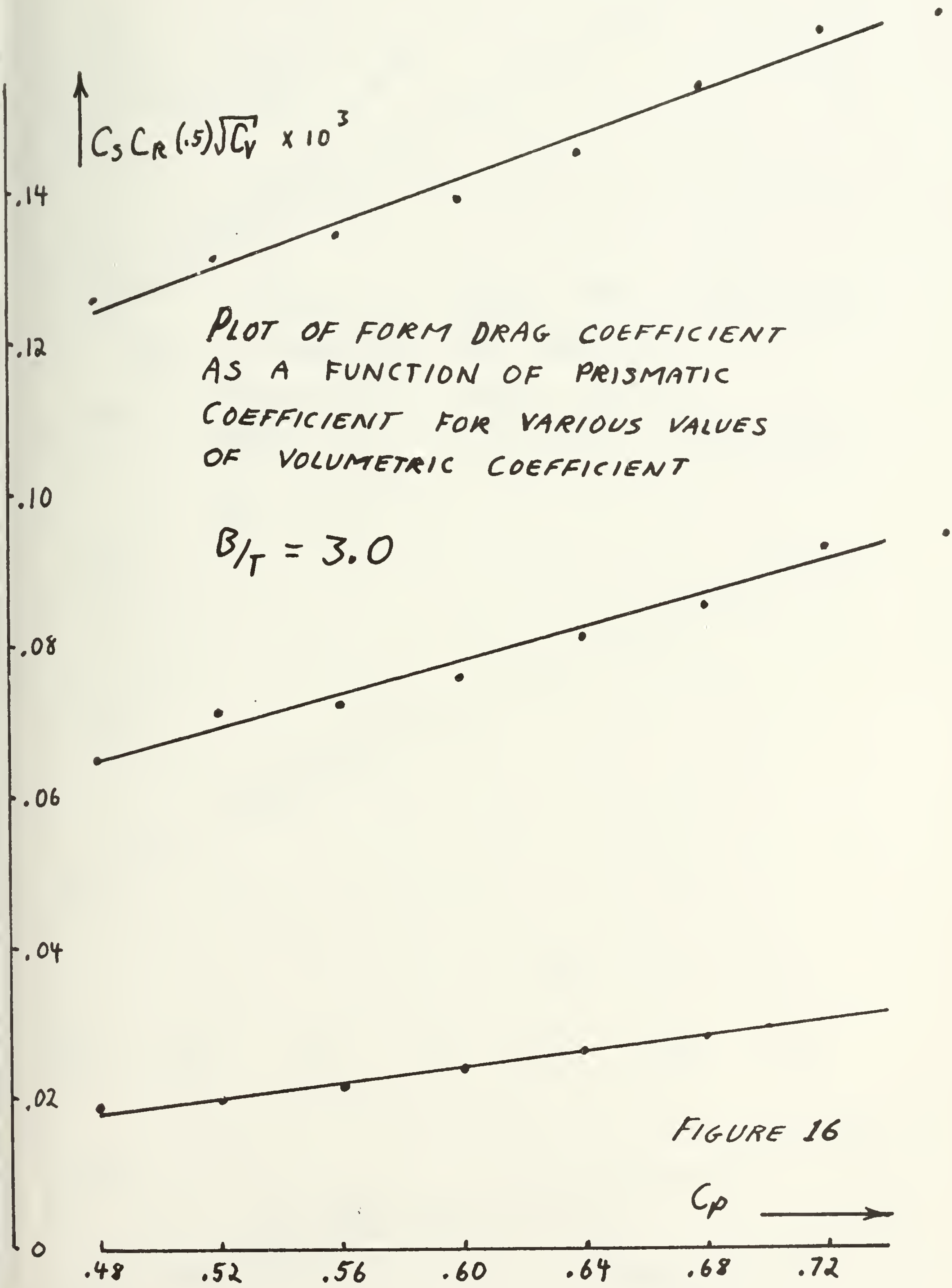
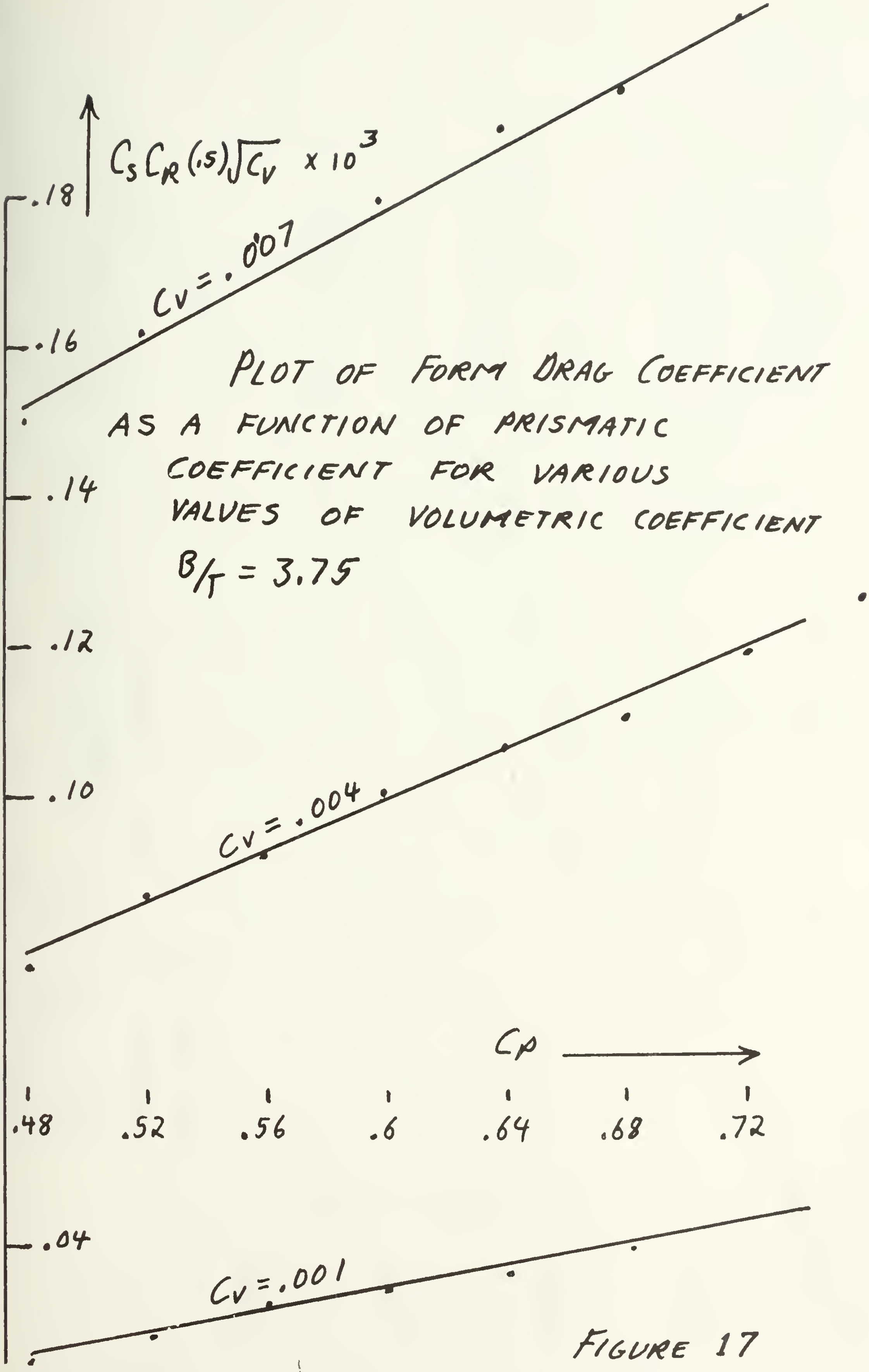

$C_S C_R (.5) \sqrt{C_V} \times 10^3$
.14
.12
.10
.08
.06
.04
.02
0
PLOT OF FORM DRAG COEFFICIENT AS A FUNCTION OF PRISMATIC COEFFICIENT FOR VARIOUS VALUES OF VOLUMETRIC COEFFICIENT
$B/T = 3.0$
C_p
.48
.52
.56
.60
.64
.68
.72

FIGURE 16



$C_S C_R(.5)\sqrt{C_V} \times 10^3$
.18
.16
.14
.12
.10
.04
CV = .007
CV = .004
CV = .001
PLOT OF FORM DRAG COEFFICIENT AS A FUNCTION OF PRISMATIC COEFFICIENT FOR VARIOUS VALUES OF VOLUMETRIC COEFFICIENT
B/T = 3.75
Cp
.48
.52
.56
.6
.64
.68
.72

FIGURE 17

PLOT OF THE FUNCTION FOR SKIN FRICTION ERROR, F_o, VERSUS C_p FOR VARIOUS VALUES OF B/T

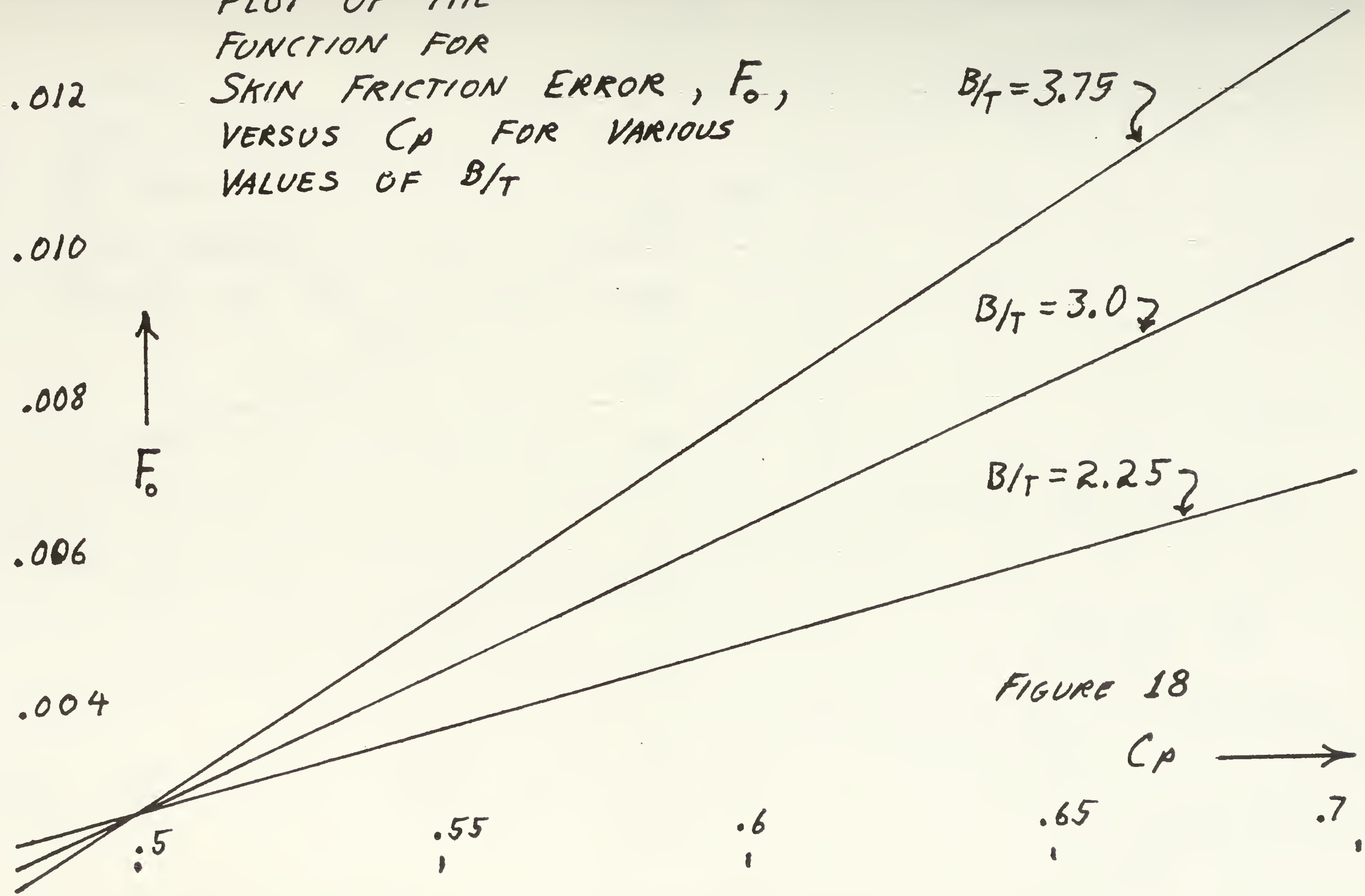


FIGURE 18

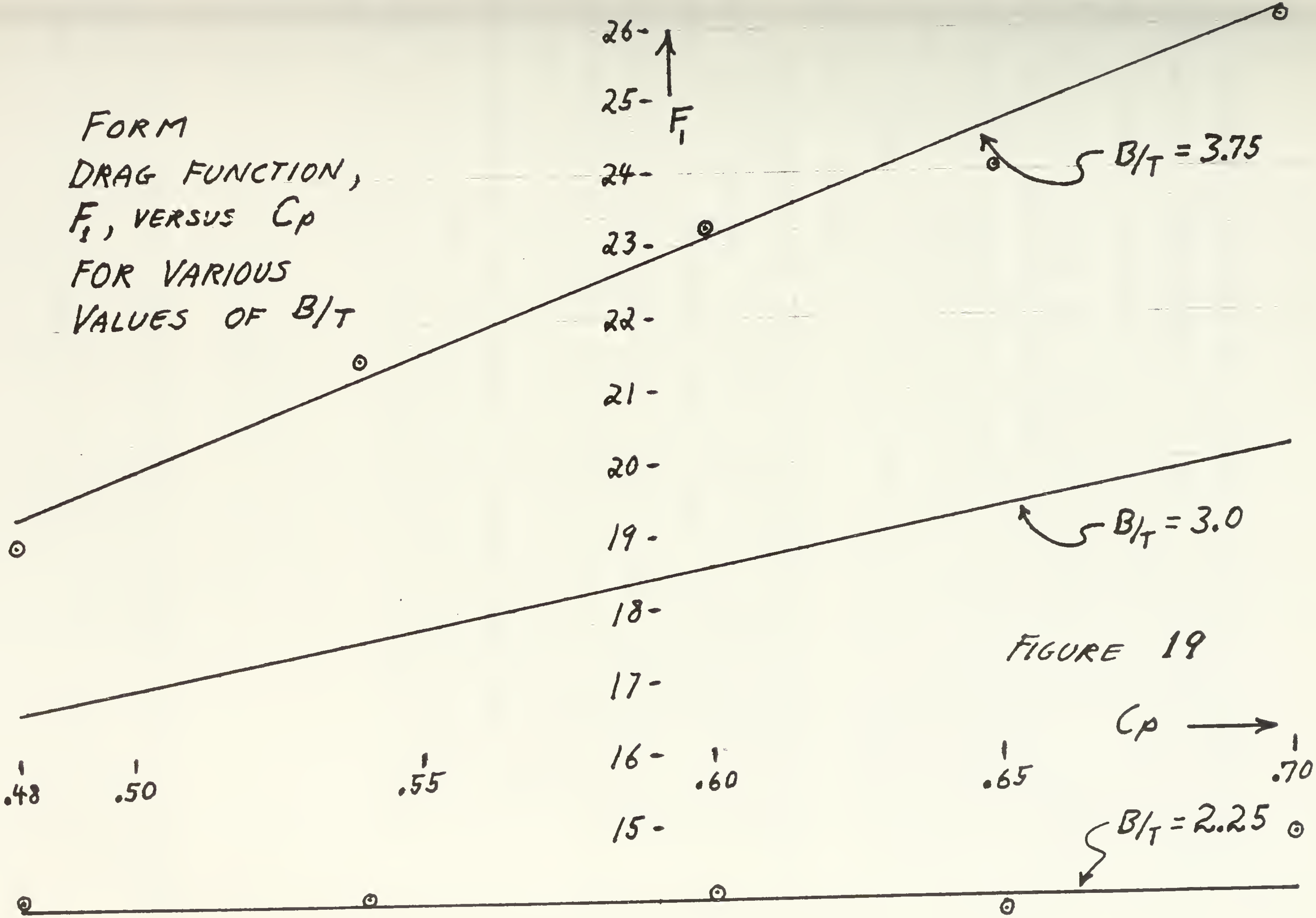

FORM
DRAG FUNCTION,
F_1, VERSUS C_p
FOR VARIOUS
VALUES OF B/T
26
25
24
23
22
21
20
19
18
17
16
15
F_1
$B/T = 3.75$
$B/T = 3.0$
$B/T = 2.25$
C_p
.48
.50
.55
.60
.65
.70

FIGURE 19

A computer program was written to do the necessary calculations and is presented in one version in Appendix A. Offsets were read and interpolated to provide offsets at .7 and .9 waterlines which were not available in reference 7. Complete full size offsets were generated for ten stations and ten waterlines for each of the 70 ships. From these offsets, ∇, S, C_v, C_p, C_m and C_S were calculated. All integrals were done using Simpson's rule. Calculations were done for vessels of 190 feet in length.

For each of the 70 ships the weighted form coefficients were calculated for 15 speeds, providing 1050 weighted forms from the 1050 ship-speed combinations. Although this thesis contains formulae for predicting form drag, they were programmed only as a means of comparing predicted form drag to $C_R(V/\sqrt{L} = .5)$. To prevent the validity of one hypothesis from depending on the validity of another hypothesis, the values of $C_R(V/\sqrt{L} = .5)$ punched from the Taylor Series were used as form drag in the calculation of wave drag. F_2 was then calculated as

$$F_2 = [C_R - C_R(.5)]\left(\frac{S}{L^2}\right)(C_v^*)^2 \qquad (57)$$

The product of the first computer program was both printed and punched for further use. Printed outputs for a number of example ships are included in Appendix C. For each of the

1050 ship-speed combinations, the following vital parameters were punched on cards for later analysis:

NAME	QUANTITY
SLR	$V/\sqrt{L}$
CCR	$CR(V/\sqrt{L})$
CR5	CR(.5)
CVST	$C_V^* \times 10^3$
CVT	$C_V \times 10^3$
CPS1	CP*
CPN	CP
SL2	S/L^2
BDR	B/T
F2	F_2

The printed output contains additional information, including F_o, F_1, S, ∇^*, Froude number, LCB*, C_m^* and C_B^*.

X. THE REGRESSION ANALYSIS

<u>The Statistical Package for the Social Sciences</u> [2] was used to conduct all regression analyses and correlation studies. This very powerful analytical tool provides extremely easy interfacing and an output containing every imaginable measure of statistical significance. Simple regression, multiple regression and stepwise inclusion multiple regression processes are available.

The 1050 ship-speed combinations were filtered to eliminate misleading data and shakey extrapolations. A ship with $C_V = .007$ and $C_p = .7$, for example, at a $V/\sqrt{L} = 1.2$ will have a residuary drag coefficient so large that it would plot off the page in reference 7 if the extrapolation were attempted. Over 100 ship-speed combinations, although extrapolated as data in reference 6, were eliminated for these reasons.

Correlation studies were conducted in an attempt to determine n in the equation

$$C_w = F_3(C_v^*)^n = F_2(C_v^*)^2 \qquad (58)$$

for the entire 1050 ship-speed combinations. After investigating various values of n by computer and calculating best values of n by hand, n was fixed at a value of 1.8 for all speeds, so that:

$$C_w = F_3(C_v^*)^{1.8} \tag{59}$$

It should be mentioned at this point that a value of n = 1.8 very slightly favors high speeds from $V/\sqrt{L}$ = 1.0 to 1.2. For lower speeds, a somewhat lower value of n would have provided a better fit. For the purposes of this thesis, however, a constant value of n = 1.8 was used for all speeds.

Due to the irregular manner with which the relationships between the form coefficients and residuary drag change with speed length ratio, a separate multiple regression analysis was run for each of the 14 speed length ratios from .55 to 1.2. In addition to the variable, CP*, a series of five sine functions of CP* was defined and made available for stepwise inclusion into each multiple regression analysis as necessary to obtain the desired fit. Since the values of F_2 were punched in the data rather than F_3, it was necessary to compute F_3 as a variable within the regression analysis program for every sample along with the terms in the Fourier sine series. Appendix B.1 contains selected listings and output printouts for one of the 14 regression analyses runs. Variables were defined as follows:

CPS1 ≡ CP*

CVST ≡ CV* x 10^3

CPSV ≡ (CPS1 - .48)/.27

$$CPSA \equiv \sin(\pi CPSV)$$

$$CPSB \equiv \sin(2\pi CPSV)$$

$$CPSC \equiv \sin(3\pi CPSV)$$

$$CPSD \equiv \sin(4\pi CPSV)$$

$$CPSE \equiv \sin(5\pi CPSV)$$

$$F_3 \equiv F_2(CVST)^{.2}$$

The Fourier sine series was limited to five terms to avoid the representation of data scatter in the final function. Each stepwise inclusion multiple regression analysis then regressed F_3 with CPS1 and the five sine terms. A constant is automatically added into the regression as the zeroth order term. The final form of the universal function, F_3, is then:

$$F_3 = CK + C_1 CPS1 + C_A CPSA + C_B CPSB + C_C CPSC$$

$$+ C_D CPSD + C_E CPSE \qquad (60)$$

The resulting values of the constants are listed in Appendix B.2 along with various measures of confidence and statistical fit. An example of a typical listing of SPSS control cards used is also provided in Appendix B.1 along with parts of the SPSS output for that particular run. It should be noted that the F_3 in the regression analyses computer program is larger than the F_3 defined in previous sections by a

factor of $(1000)^{.2} = 3.98$ due to the definition of CVST,

$$CVST \equiv CV^* \times 10^3 \tag{61}$$

To use this universal function for the prediction of wave drag, F_3 must be divided by $(1000)^{.2}$ or:

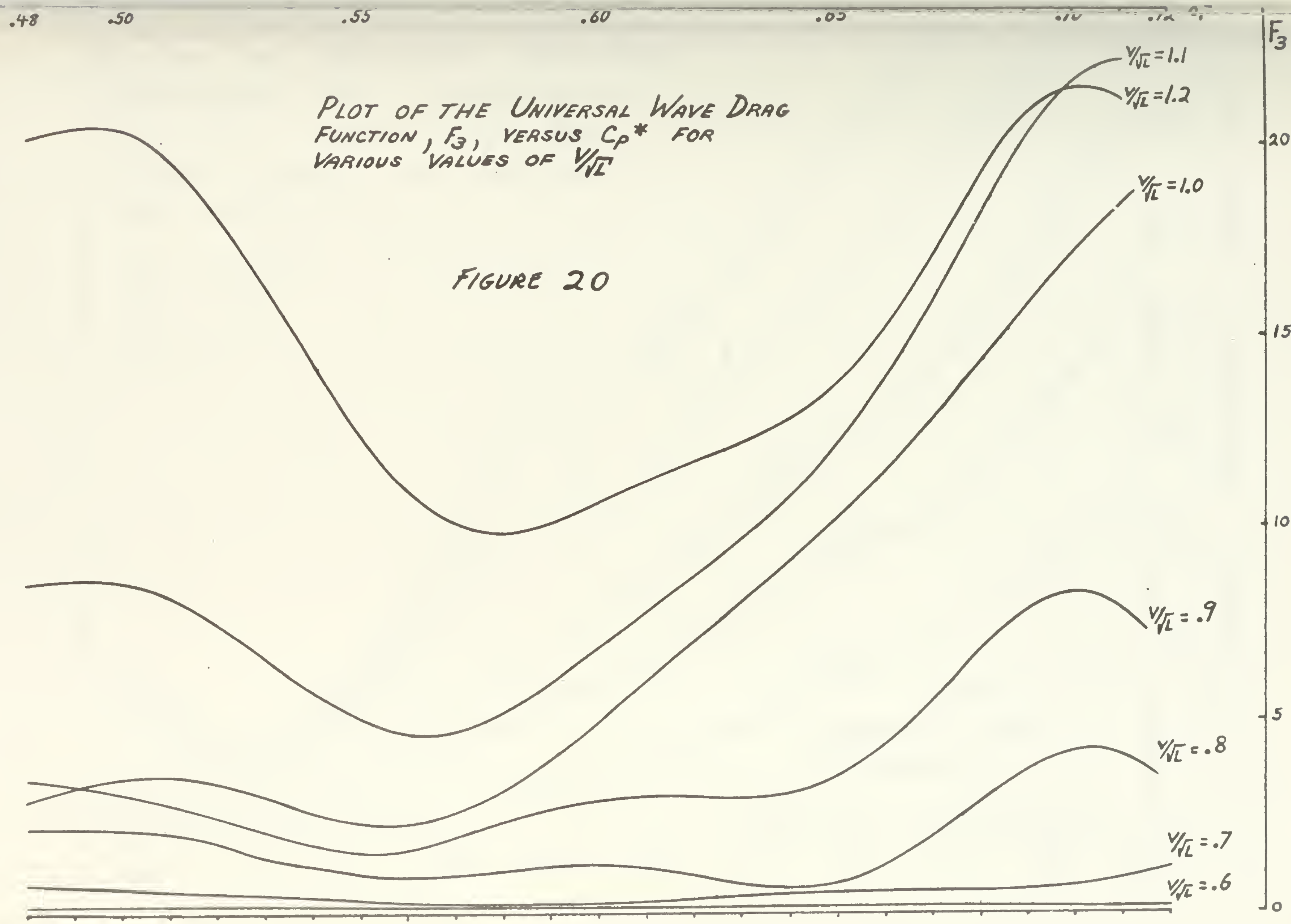
$$F_3 = F_2(CV^*)^{.2} = F_2(CVST)^{.2}/(1000)^{.2} \tag{62}$$

Tables of $F_3 = F_2(CV^*)^{.2}$ are provided in Appendix B.3.

XI. WAVE DRAG CONCLUSIONS

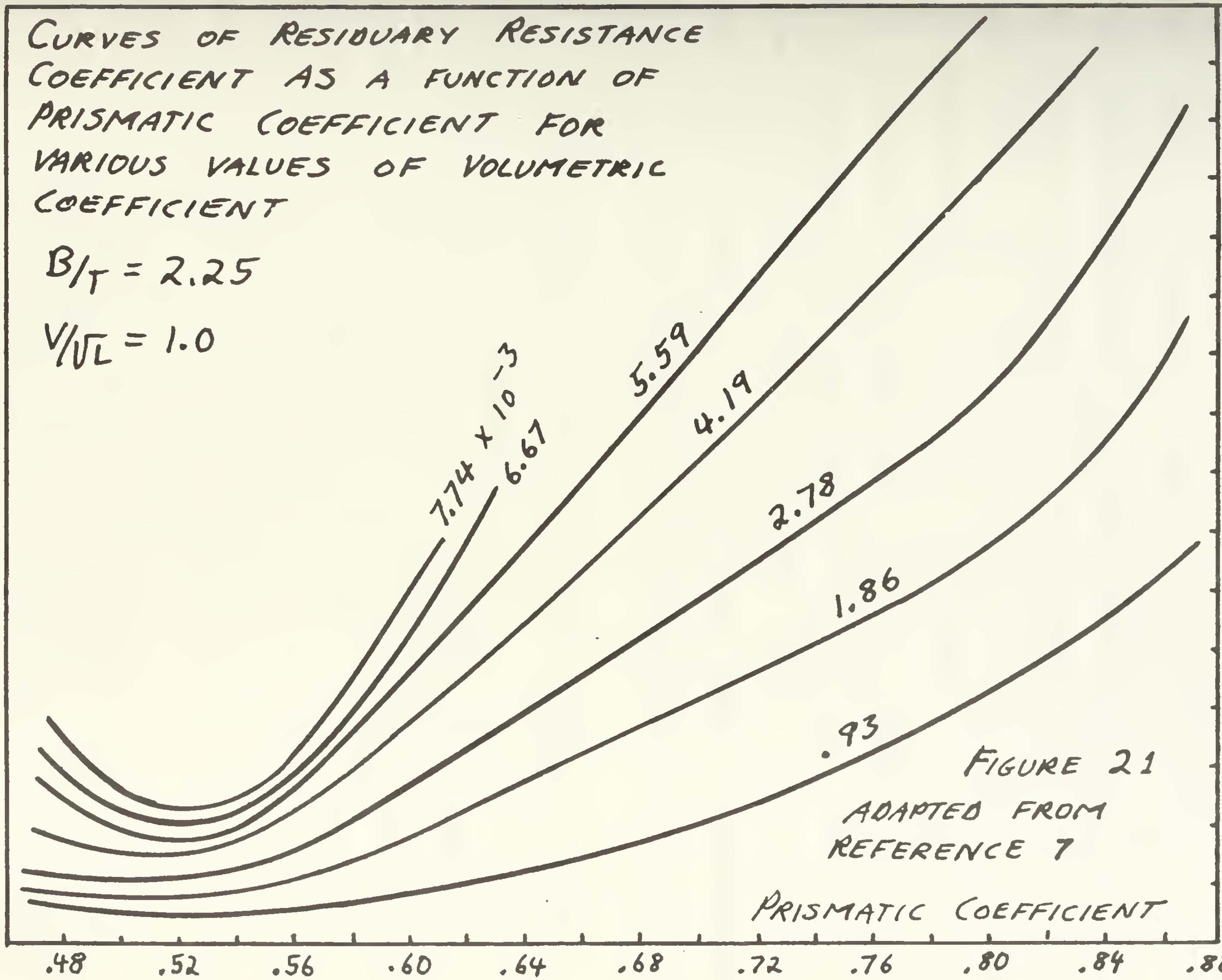
For each value of $V/\sqrt{L}$, F_3 constitutes an estimate of a universal wave drag function of C_p^* alone and represents wave drag coefficient per unit weighted volumetric coefficient raised to the 1.8 power. With the use of the weighted coefficients of form, C_v^* and C_p^*, and with the implementation of the universal wave function, F_3, the representation of wave drag is simplified considerably. The entire Taylor Standard Series, for example, is collapsed onto one sheet of paper as represented in Figure 20. A family of curves of F_3 versus C_p^* is plotted in this illustration with one curve for each value of $V/\sqrt{L}$. It is reassuring that the curves of F_3 versus C_p^* for various values of $V/\sqrt{L}$ show minima similar to those found using the standard coefficients of form. Figure 21 illustrates these minima for the Taylor Standard Series data in reference 7.

The value of the exponent of displacement (or C_v) would be expected to be 2.0 from Mitchell's [14] linear ship theory. Weinblum [26] states that wave drag was approximately proportional to displacement to the 1.6 power. With the form drag subtracted out of residuary drag, it is concluded from the results of this thesis that wave drag is approximately proportional to the displacement raised to the 1.8 power. Thus half of the discrepancy between the theoretical value of 2.0 and the previously observed value of 1.6 has been explained and



PLOT OF THE UNIVERSAL WAVE DRAG FUNCTION, F_3, VERSUS C_p* FOR VARIOUS VALUES OF $V/\sqrt{L}$

FIGURE 20


CURVES OF RESIDUARY RESISTANCE COEFFICIENT AS A FUNCTION OF PRISMATIC COEFFICIENT FOR VARIOUS VALUES OF VOLUMETRIC COEFFICIENT
B/T = 2.25
V/√L = 1.0
7.74 x 10^-3
6.67
5.59
4.19
2.78
1.86
.93
FIGURE 21
ADAPTED FROM REFERENCE 7
PRISMATIC COEFFICIENT
RESIDUARY RESISTANCE COEFFICIENT
.48
.52
.56
.60
.64
.68
.72
.76
.80
.84
.88
0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0

removed.

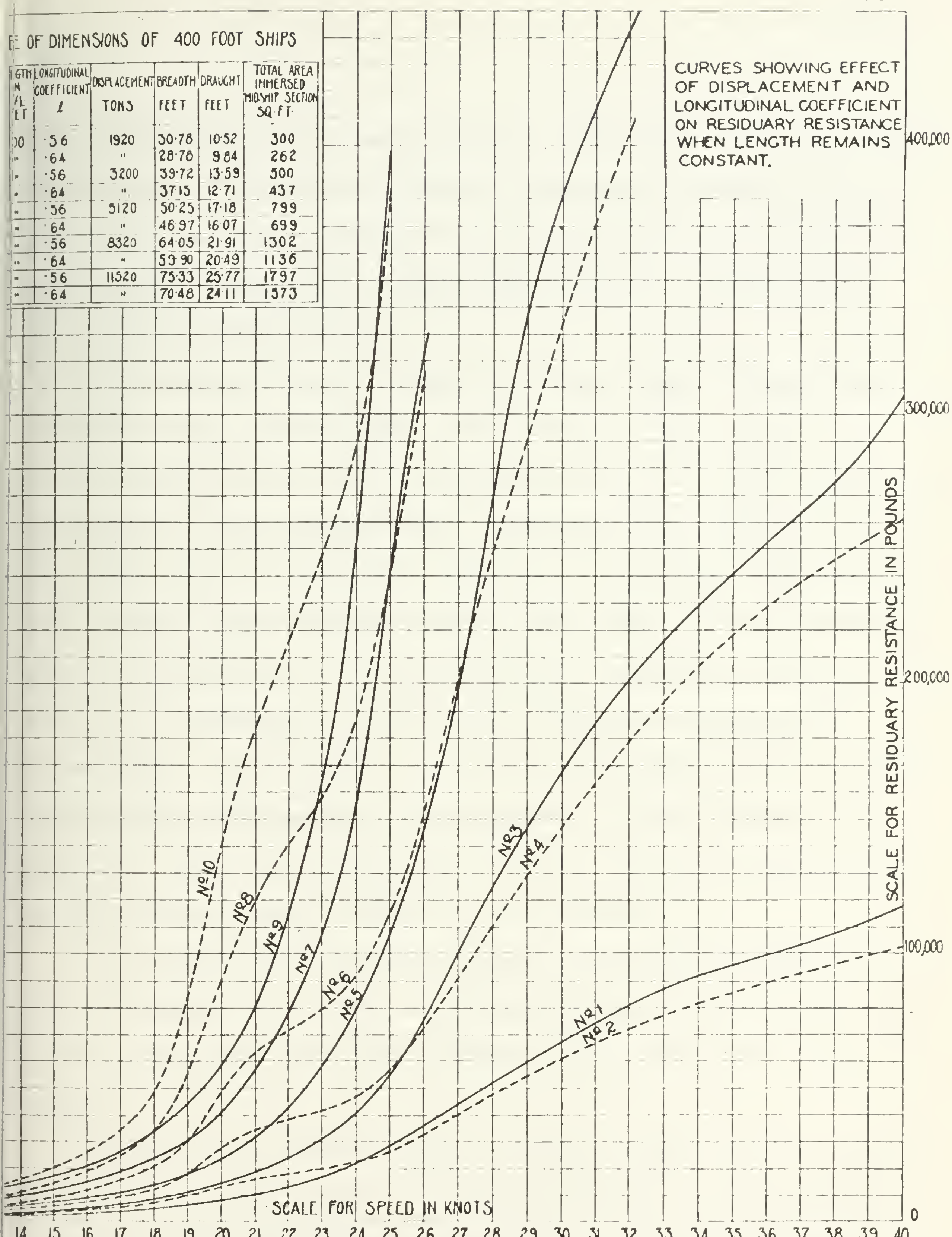
Figure 22 illustrates the effect of both C_p and of C_v on the residuary resistance. Some sample curves of wave drag coefficient predicted by the universal wave drag function and by the Taylor Standard Series are provided for comparison in Appendix C. From these curves it can be seen that wave drag is predicted fairly well by the universal wave drag function in most cases. In almost every case, the humps and hollows are reflected in the predicted wave drag curve. The earlier rise in the wave drag curve for high values of C_p and the later but steeper rise in the wave drag curve for low values of C_p are both well predicted by the universal wave drag function.

The wave drag of vessels with lines differing greatly from the Taylor Standard Series is not predicted as well as the wave drag of vessels in the Taylor Series. Some sample curves of predicted wave drag and wave drag from model tests are provided for comparison in Appendix D. In most cases, wave drag is overpredicted for values of $V/\sqrt{L}$ above 1.0 and underpredicted for values of $V/\sqrt{L}$ below 1.0. There are several possible reasons for these errors.

At high speeds, vessels with wide sections, full waterlines and flat buttock lines aft will derive more dynamic lift than vessels with deep sections, hollow waterlines and full buttock lines aft. As a result, the former will tend to squat

E OF DIMENSIONS OF 400 FOOT SHIPS

GTH N /L ET	LONGITUDINAL COEFFICIENT l	DISPLACEMENT TONS	BREADTH FEET	DRAUGHT FEET	TOTAL AREA IMMERSED MIDSHIP SECTION SQ·FT·
00	·56	1920	30·78	10·52	300
"	·64	"	28·78	9·84	262
"	·56	3200	39·72	13·59	500
"	·64	"	37·15	12·71	437
"	·56	5120	50·25	17·18	799
"	·64	"	46·97	16·07	699
"	·56	8320	64·05	21·91	1302
"	·64	"	59·90	20·49	1136
"	·56	11520	75·33	25·77	1797
"	·64	"	70·48	24·11	1573



OM REFERENCE 22

FIGURE 22

more than the latter at high speed. The vessel with the deep sections and full buttocks aft may have less residuary drag at low speed than the vessel with wide sections and flat buttocks but will have more drag at high speed due to the additional wave drag caused by squat.

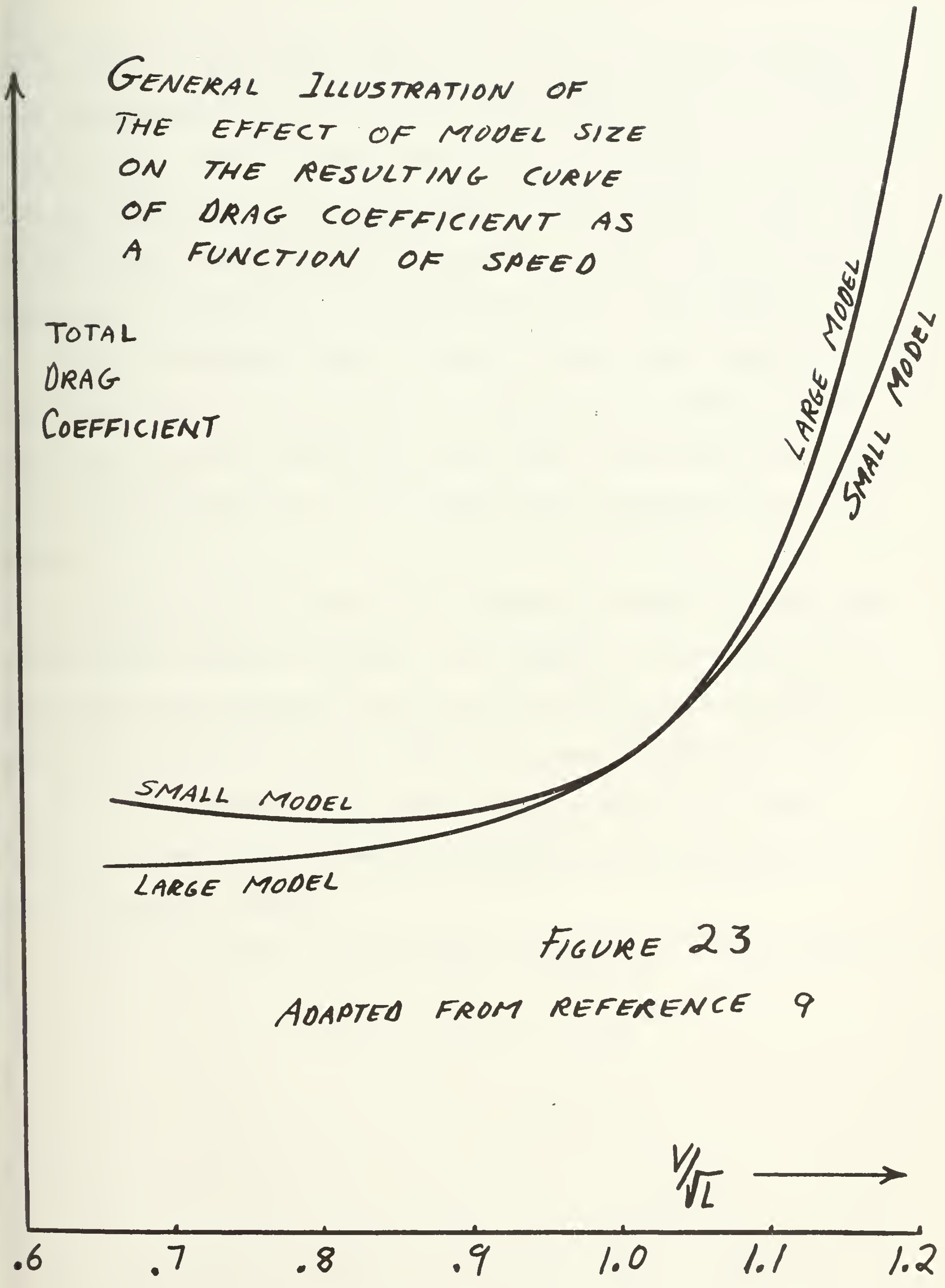
The Taylor Standard Series parent has deep V-shaped sections and full buttocks aft. The survey launch and the 5.5 meter yacht "Antiope", on the other hand, have very straight buttocks and wide sections aft, providing more squatting surface than the other vessels. Although the destroyer and patrol boat models have V-shaped sections aft, they are not very deep and the buttocks are not badly curved. Prediction formulae based on the Taylor Series would therefore be expected to underpredict the resistance of the latter three vessels at low speed and to overpredict at high speed. It may be seen from Appendix D that the patrol boat is the only one of these four which does not behave completely as expected.

In addition to the differences in wave drag coefficient due to dynamic lift from the afterbody lines, other differences in the lines may also cause errors in the prediction of wave drag.

Variations in model size and testing techniques may also explain some of the error in predicting the wave drag coefficient of those models sampled which were not in the Taylor Series. As discussed previously, flow separation and wave

interactions may cause scale effects over a small range of model size. Reference 9 discusses scale effects in hydrodynamic testing in great detail. Many plots are presented of predicted resistance coefficient versus speed curves to provide comparisons between larger and smaller geosims. It was noted that even for widely differing hull forms, from merchant ships to racing yachts, the smaller geosim has a larger resistance coefficient at low speeds and the larger geosim has a larger resistance coefficient at higher speeds. The cross over point is a little above a $V/\sqrt{L}$ of 1.0. This is shown roughly in Figure 23. If the wave drag coefficient prediction curves in Appendix D are compared to Figure 23, it will be seen that regardless of the causes, the errors show strong similarities to model scale effects. The predicted wave drag coefficient curves, based on the regression analysis of the Taylor Standard Series, follow the general trend expected for the larger geosim. The model test resistance curves for most of the models having hull forms unlike the Taylor parent follow the general trend expected for the small geosim, even though they were actually 12.5 to 16 feet in length.

Since the change in the drag curve predicted from the Taylor Series caused by afterbody lines which derive more dynamic lift at high speed is somewhat similar to the change caused by testing a smaller model, i.e., higher drag at low speed and lower drag at high speed, then it would be very


GENERAL ILLUSTRATION OF THE EFFECT OF MODEL SIZE ON THE RESULTING CURVE OF DRAG COEFFICIENT AS A FUNCTION OF SPEED
TOTAL DRAG COEFFICIENT
LARGE MODEL
SMALL MODEL
SMALL MODEL
LARGE MODEL
FIGURE 23
ADAPTED FROM REFERENCE 9
V/√L
.6
.7
.8
.9
1.0
1.1
1.2

difficult to tell which effect, if any, was contributing to the underprediction at low speed and overprediction at high speed of any smaller models which have flat buttock lines. The survey launch may be in this category although the model was 16 feet long, and it is more likely that the flat buttocks caused the wave drag to be overpredicted at high speeds.

Since "Antiope" was 24.3 feet in waterline length and the destroyer was a 20 foot model, it can only be their relatively straight buttock lines which cause their wave drag coefficients to be underpredicted at low speed and overpredicted at high speed.

Although it is difficult to tell from their lines, the trawlers may derive slightly more dynamic lift at high speed than the Taylor models which could explain the underprediction of their wave drag at low speed and overprediction at high speed. In addition, the trawler models were 12.5 feet in length and may suffer some scale effect when compared to the 20 foot Taylor models.

Lines drawings are provided in Figures 8 and 25 through 29.

XII. FORM DRAG CONCLUSIONS

Plots of form drag coefficient,

$$\frac{R_f}{1/2\rho V^2 L^2} = C_S C_R\left(\frac{V}{\sqrt{L}} = .5\right)\sqrt{C_v} \tag{63}$$

as a function of C_p for three values of C_v and three values of B/T are provided with data points in Figures 15, 16 and 17 to show how the data was faired. Similarly, plots of form drag coefficient as a function of C_v for three values of C_p and three values of B/T are provided in Figures 12, 13 and 14. From these graphs, it is evident that form drag is very nearly proportional to both C_p and C_v. Although data for the B/T of 3.0 is plotted, it was not used to derive the equations for F_o and F_1 for the reasons previously discussed in Chapter V. Form drag was therefore assumed to be linear in B/T between the values of 2.25 and 3.75.

The resulting equations relating F_o and F_1 to B/T and C_p are as follows:

$$F_o = .0027 + (C_p - .5)[.021 + .02033(\frac{B}{T} - 2.25)] \tag{64}$$

$$F_1 = 14.0 + (\frac{B}{T} - 2.25)[4.0 + 20.7(C_p - .5)] \tag{65}$$

The form drag coefficient is then

$$C_f = (C_o + C_1)(\frac{L^2}{S}) \qquad (66)$$

where C_o is defined by Equation (38) and C_1 is defined by Equation (36), or

$$C_f = (F_o + F_1 C_v)(\frac{L^2}{S}) \qquad (67)$$

With each of the plots comparing predicted wave drag to model test results is listed the predicted form drag and that of the model test. Figure 19 also contains data points which represent the value of F_1 calculated from the equation for F_o and the residuary resistance coefficient at $V/\sqrt{L} = .5$ from reference 7. The plotting of these calculated "data" points for F_1 is not a complete demonstration of the accuracy of the equation since it assumes the accuracy of the equation for F_o. The best evaluation of the accuracy of the equations for F_o and F_1 is probably the direct comparison of the predicted value to the value of the residuary resistance coefficient at a $V/\sqrt{L}$ of .5 from reference 7.

Form drag is predicted reasonably well for all vessels in the Taylor Standard Series as may be seen from Appendix C. Prediction is best for those vessels with volumetric coefficients in the middle of the range of data, approximately .004.

For heavier vessels, form drag is underpredicted increasingly with volumetric coefficient. This effect is simply the

manifestation of the slight nonlinearity of form drag with displacement. The effects of C_p and B/T seem to be adequately represented by the Equations (64), (65) and (66) for the ships of medium and heavy volumetric coefficients.

For extremely fine vessels, the effects of C_p become slightly overpredicted. As a result, form drag for vessels with low C_p and low C_v is underpredicted but is overpredicted for vessels with high C_p and the same C_v. This is another manifestation of the slight nonlinearity of form drag with displacement.

For hull forms differing from the Taylor lines, presented in Appendix D, it appears that form drag is predicted relatively well for slender hulls but not so well for vessels with higher volumetric coefficient. The old destroyer in Appendix D, for example, is predicted reasonably well with a volumetric coefficient of .00139. The round bottom patrol boat in Appendix D is predicted less accurately with a volumetric coefficient of .00246. The survey launch in Appendix D is underpredicted by about 500% with a volumetric coefficient of .0043. Both trawler models are underpredicted by over 100% with volumetric coefficients of .00691 and .00830. The form drag coefficient of the 5.5 meter yacht "Antiope" with a volumetric coefficient of .00627 is predicted reasonably well as long as the fairbody beam to draft ratio is used. The form drag coefficient predicted by the computer program for "Antiope" was inaccurate because the

full draft was automatically used to calculate the beam to draft ratio. A misleading beam to draft ratio of only 1.35 was then entered in the prediction formulae for F_1 and F_o. It is interesting that "Antiope" is predicted so well when the other vessels of similar volumetric coefficient are so badly underpredicted.

Taylor Series models with high volumetric coefficient are also predicted much more accurately than the trawlers. Few commercial vessels whose feasibility depends on carrying capacity and acquisition cost can justify the fine lines of the Taylor Standard Series. Merchant ships, for example, almost always have some parallel middle body and shoulders which may generate additional wave systems and induce flow separation. The trawlers have propeller apertures and may not have afterbody lines as smooth as the Taylor models or the 5.5 meter yacht. The Taylor parent hull form is mathematical and carefully avoids harsh curvatures. It is difficult to conceive of any commercial hull form which would treat the boundary layer more gently than one with the Taylor afterbody lines. A 5.5 meter yacht is a racing machine, the design of which is not constrained by practical considerations such as propeller apertures and carrying capacity. It might be expected therefore that a racing yacht would have less form drag than a fishing trawler of similar volumetric coefficient. Lines drawings of these vessels are provided for comparison in Figures 25 through

29. The heavier of the trawlers, it should be pointed out, is completely outside the range of volumetric coefficient sampled by the regression analyses in this thesis. If the lines of the trawlers do not treat the boundary layer as gently as the 5.5 meter yacht or the Taylor Series models, then it would take only a small region of separated flow to explain the 100% difference in form drag coefficient between the trawlers and the other vessels.

The 500% error in predicting the form drag of the survey launch cannot be explained by subtle changes in the afterbody lines or by any inaccuracy in the prediction formula. With a volumetric coefficient of .0043, a reasonably slender vessel well within the range covered by the prediction formula, a form drag coefficient of 2.5×10^{-3} is about five times too large and indicates that the boundary layer must have separated from the afterbody or else the transom must have been submerged deeper than the design waterline.

Although the equations for F_o and F_1 are only artificial formulas fitted to the data rather than based on physical laws, there are some interesting characteristics to the gross behavior of F_o and F_1.

$$F_o = .0027 + (C_p - .5)[.021 + .02033(\frac{B}{T} - 2.25)]$$

$$F_1 = 14.0 + (\frac{B}{T} - 2.25)[4.0 + 20.7(C_p - .5)]$$

For ships with low values of C_p near .5, skin friction error becomes a constant independent of beam to draft ratio. For ships with low values of beam to draft ratio near 2.25, on the other hand, F_1 becomes a constant independent of prismatic coefficient.

XIII. WAVE DRAG RECOMMENDATIONS

The range of data used in this thesis is limited to that which was available in the time available. The 1050 ship-speed combinations generated, while a substantial number, included speed length ratios only through 1.2. It is recommended that this effort be extended through higher speeds. If higher speeds are attempted using the Taylor Standard Series as a data base, it will be found that the range of C_v for which data is available is narrowed considerably from that of the lower speeds, eliminating the fuller ships. It is likely, therefore, that any investigation of higher ship speeds will have to be done using either destroyer type hull forms such as Series 64 or a high speed Trawler Series.

In addition to the limits on speed length ratio, the 1050 ship-speed combinations generated for this thesis included, for most speeds, only those values of C_v between .001 and .006. This range of C_v is equivalent to a range of displacement length ratio of 28.6 through 171.4, i.e., very slender ships. These values of displacement length ratio are limited, for the most part, to military vessels. Extending the range of displacement length ratio to 400 or C_v to a value of .014 would include most interests in the field of naval architecture.

If the sectional area curve is normalized to 1.0, then the displacement is non-dimensionalized and becomes equal to C_p. If $L = 1.0$ and $A_x = 1.0$, then:

$$\nabla = \int_{x=0}^{x=L} A(x)\,dx = \int_0^1 \frac{A(x)}{A_x L}\,dx = C_p = \mu_o \tag{68}$$

where μ_o is the zeroth moment of the sectional area curve. The longitudinal prismatic coefficient may be thought of as a zeroth moment of the sectional area curve. Similarly, a first moment of the sectional area curve may be defined as:

$$\int_{x=0}^{x=L} xA(x)\,dx = \int_{x=0}^{x=1} \frac{xA(x)}{A_x L}\,dx = (C_p)(LCB) = \mu_1 = \mu_o LCB \tag{69}$$

and LCB becomes the ratio of the first moment to the zeroth moment of the sectional area curve. The second moment will then describe the fullness of the ends more specifically. The third moment will describe the asymmetry of the sectional area curve in greater detail. The second and third moments together may be used to describe the momental skewness of the sectional area curve. These and higher moments of the sectional area curve may be defined and used as higher order terms in regression analyses. Weighted variables could be defined, as was done in this thesis, to eliminate the dependence on beam to draft ratio. With a sufficient number of terms, it would seem that the hull form could be adequately described so that wave drag could be predicted even for vessels not geometrically similar.

In this thesis, only the gross first order effects of displacement and beam to draft ratio were collapsed out of the

data. Many higher order effects such as LCB were, by the use of the Taylor Series, carefully avoided. Although the wave drag of a hull should be predictable from a few well chosen gross parameters without addressing every detail of the hull, there are many variables evaluated in regression analyses of total drag [16 and 23] which change drastically in relative importance. Reference 1 discusses the relative contributions of these parameters in great detail and presents them all in a single compact illustration, re-drawn as Figure 24. From the behavior of the correlation of these parameters, it may be anticipated that the variables will have to be very carefully chosen in order to take into account differences in hull lines which may have the same basic form coefficients.

CORRELATION BETWEEN HULL FORM PARAMETERS AND TOTAL RESISTANCE COEFFICIENT, C_{TL}

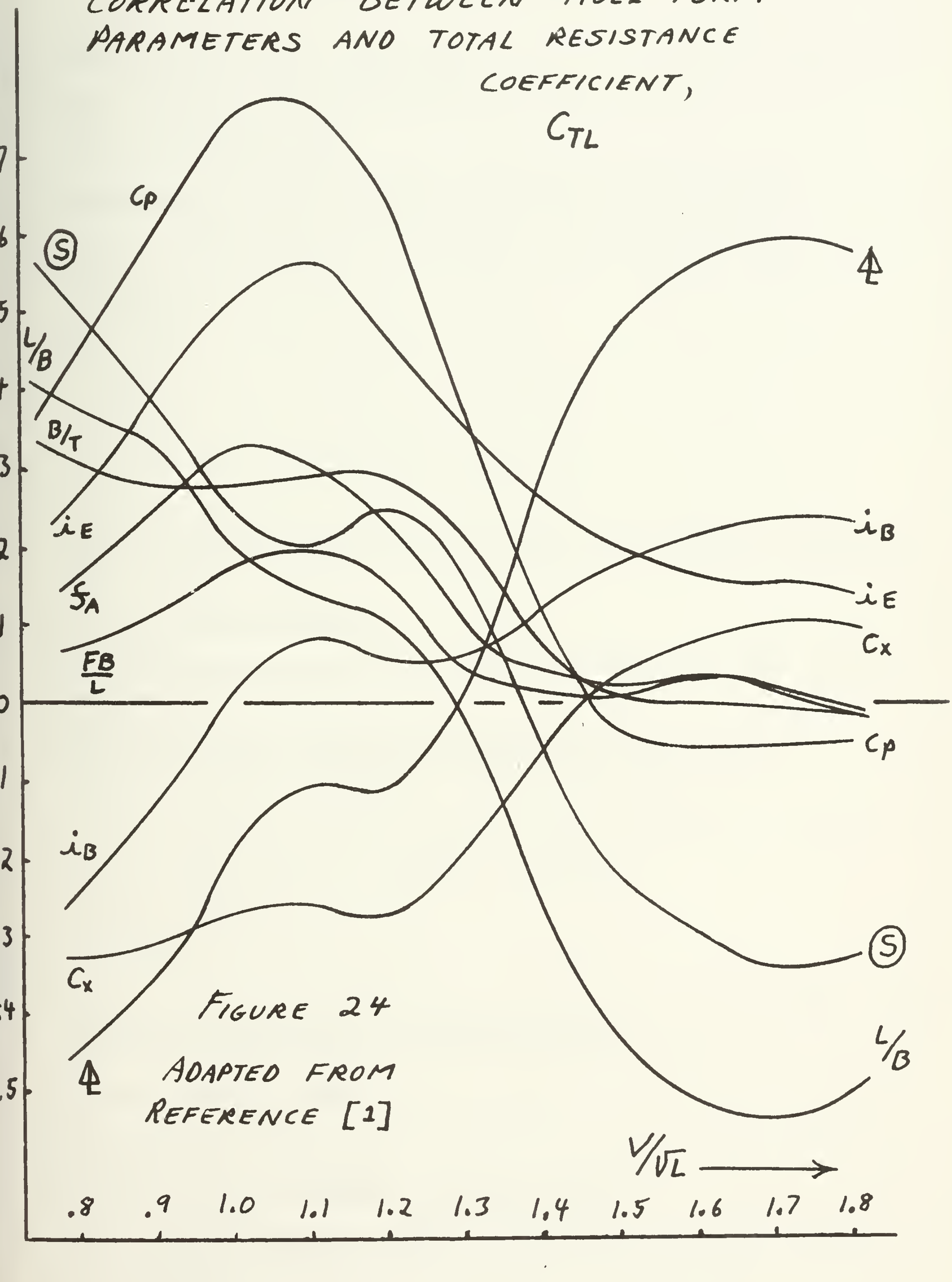


FIGURE 24

ADAPTED FROM REFERENCE [1]

NOTATION FOR FIGURE 24

A_A = total section area at the AP

A_B = total section area at the FP

AP = after perpendicular

A_x = total section area at the station of maximum area

B_x = beam at the station of maximum section area on L_{WL}

$C_p = \nabla/(L_{WL}A_x)$

$C_{TL} = R_T L_{WL}/\Delta V^2$

$C_x = A_x/(B_x T_x)$

$f_A = A_A/A_x$

$f_B = A_B/A_x$

FB = position of the longitudinal center of buoyancy measured from the FP

FP = forward perpendicular

i_B = angle of the buttock at 1/4 T_W at station $L_{WL}/20$ forward of the AP

i_E = entrance angle measured between the centerline and a tangent to the designer's waterline at the FP

L = ship or model length measured on the designer's waterline

R_T = total resistance of the hull in pounds

S = wetted surface

Ⓢ = $S/\nabla^{2/3}$

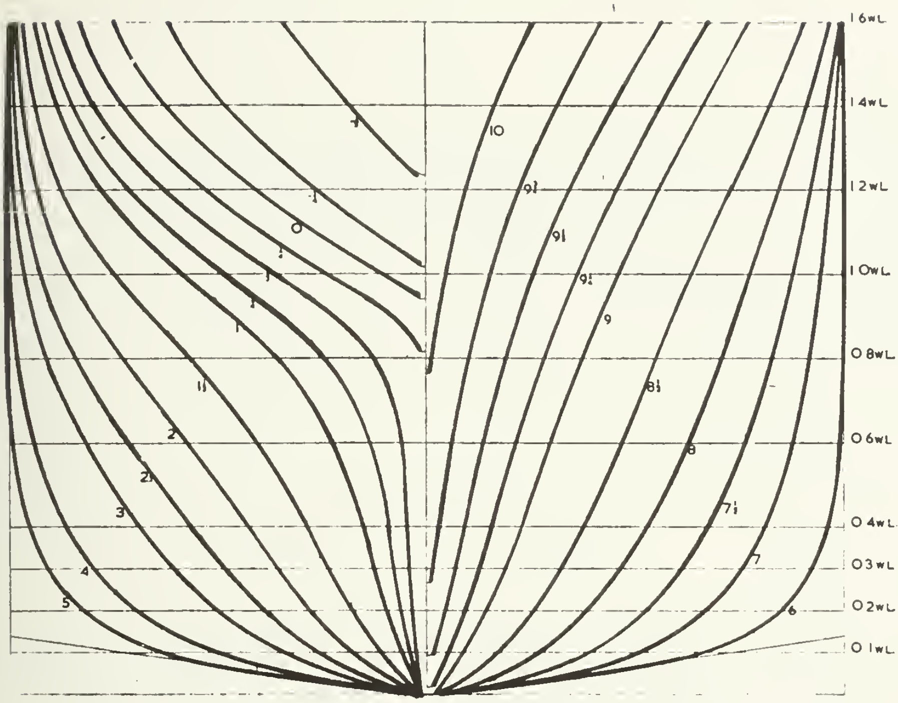
T_x = draft measured from the designer's waterline to the lowest point of the station of maximum area

V = ship speed in knots

Δ = displacement in tons

∇ = volume of displacement in cubic feet

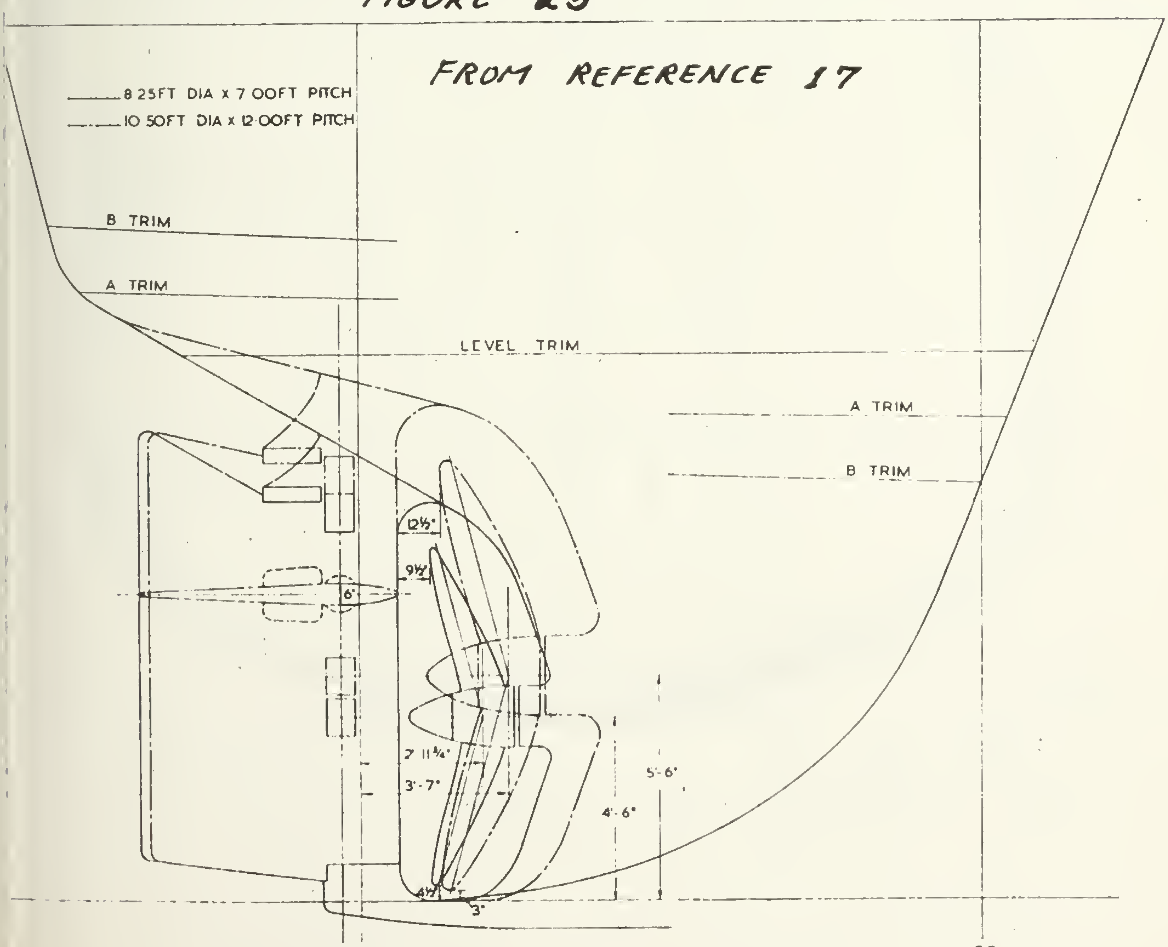
Ⓛ = $\Delta/(.01L_{WL})^3$, displacement-length ratio



—BREADTH–DRAUGHT VARIATION GROUP. BODY PLAN FOR MODEL XF (PARENT)
$B/d = 2 \cdot 00$, $L/\nabla^{1/3} = 4 \cdot 85$

FIGURE 25

FROM REFERENCE 17



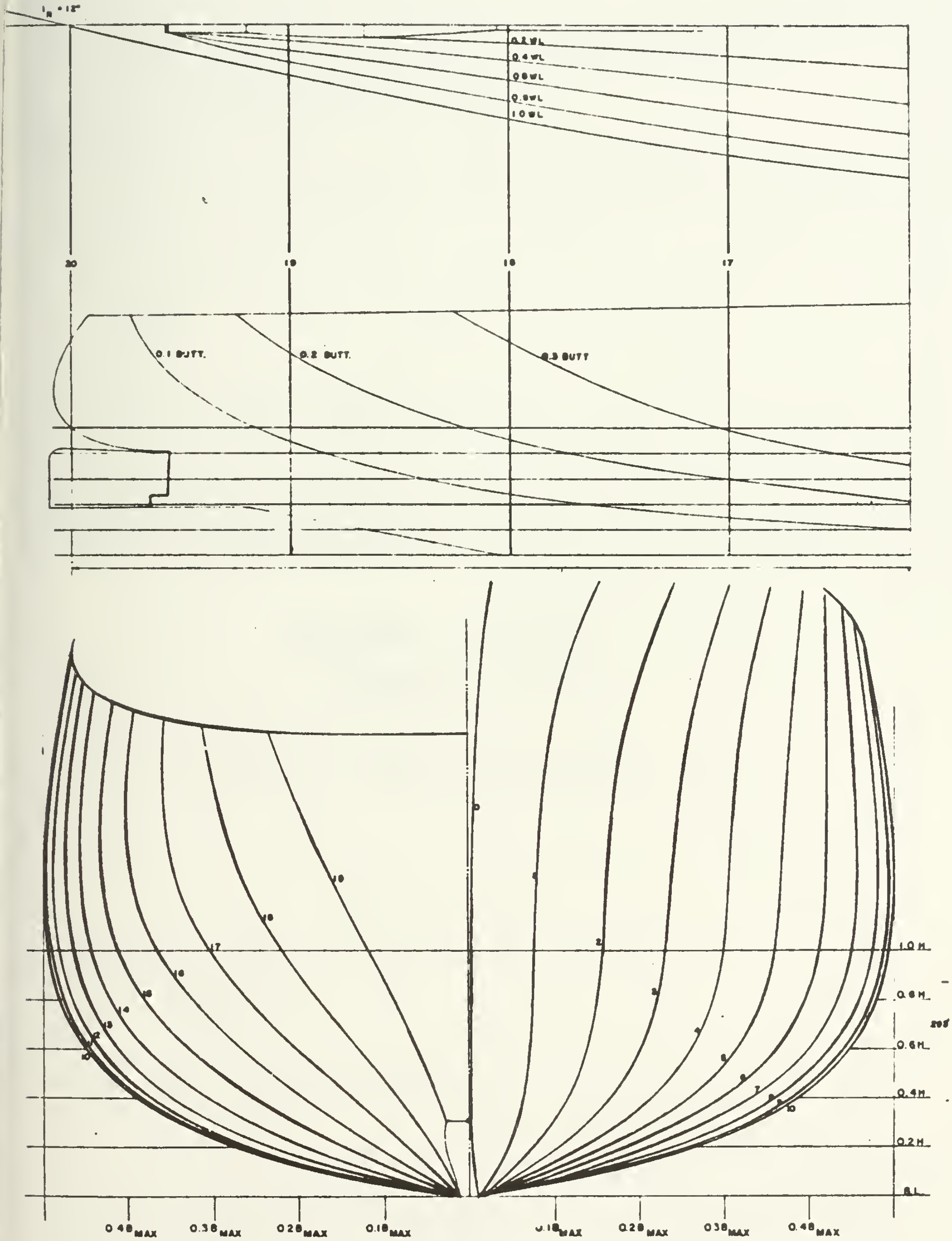
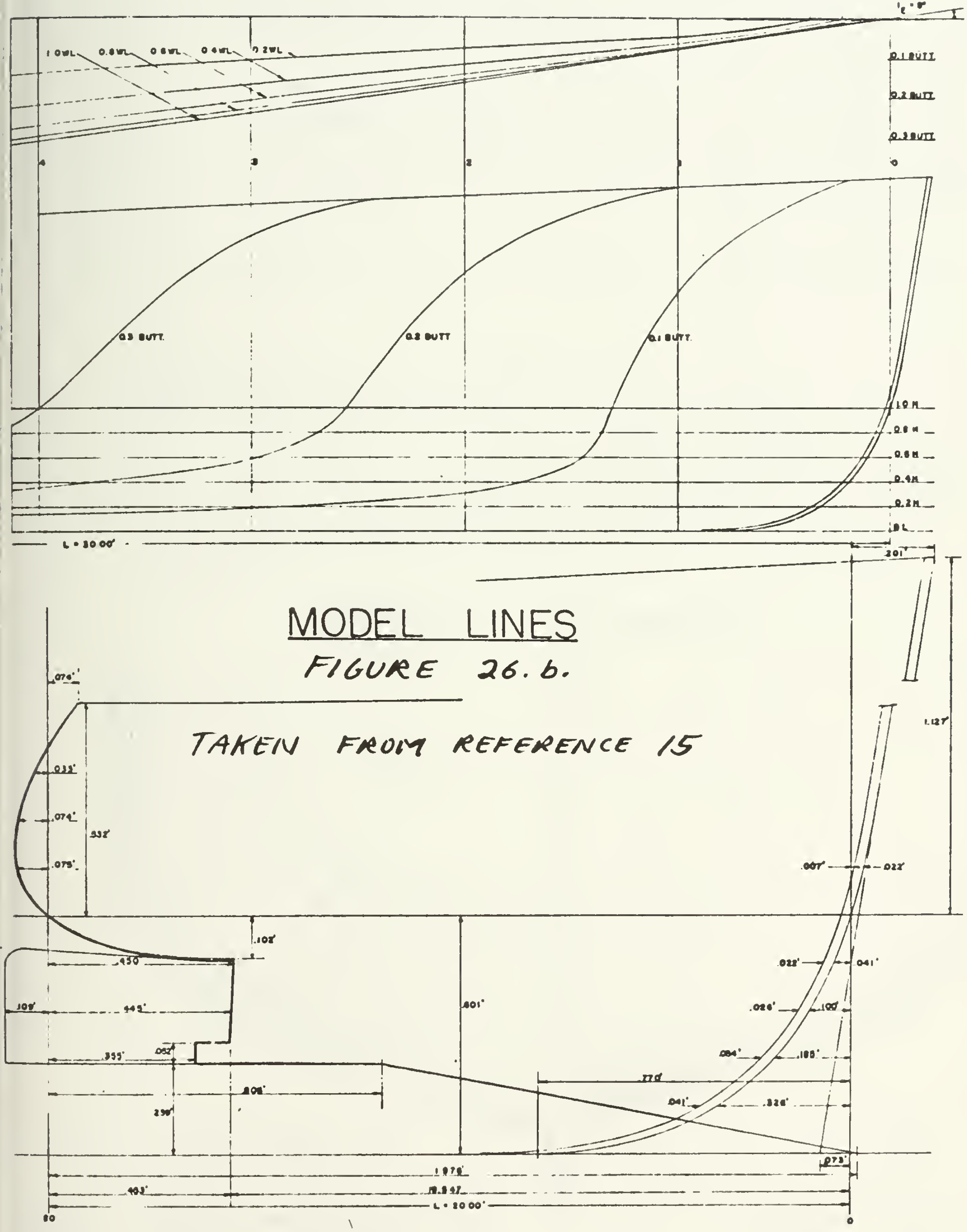


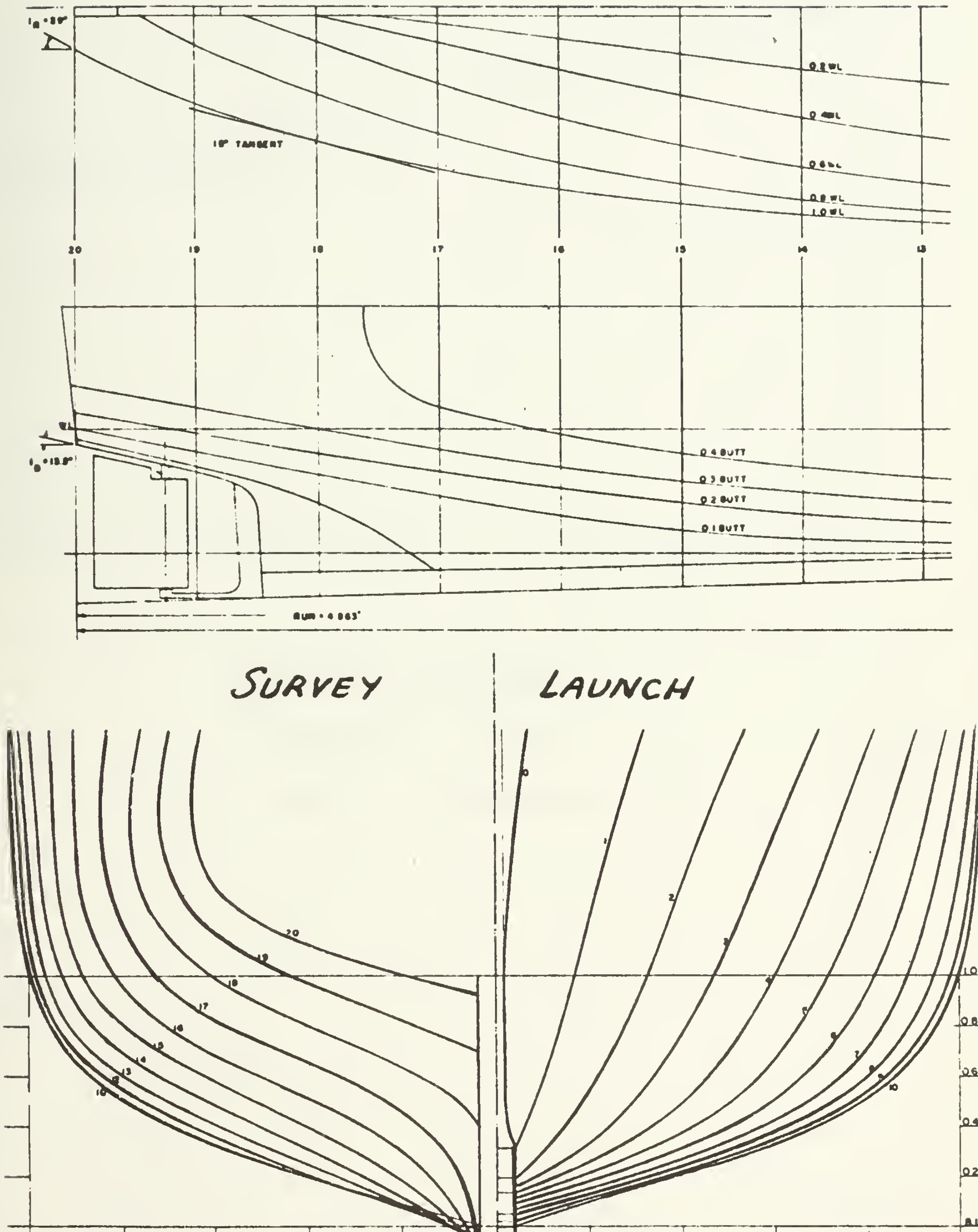
FIGURE 26.a. TAKEN FROM REFERENCE 15



MODEL LINES

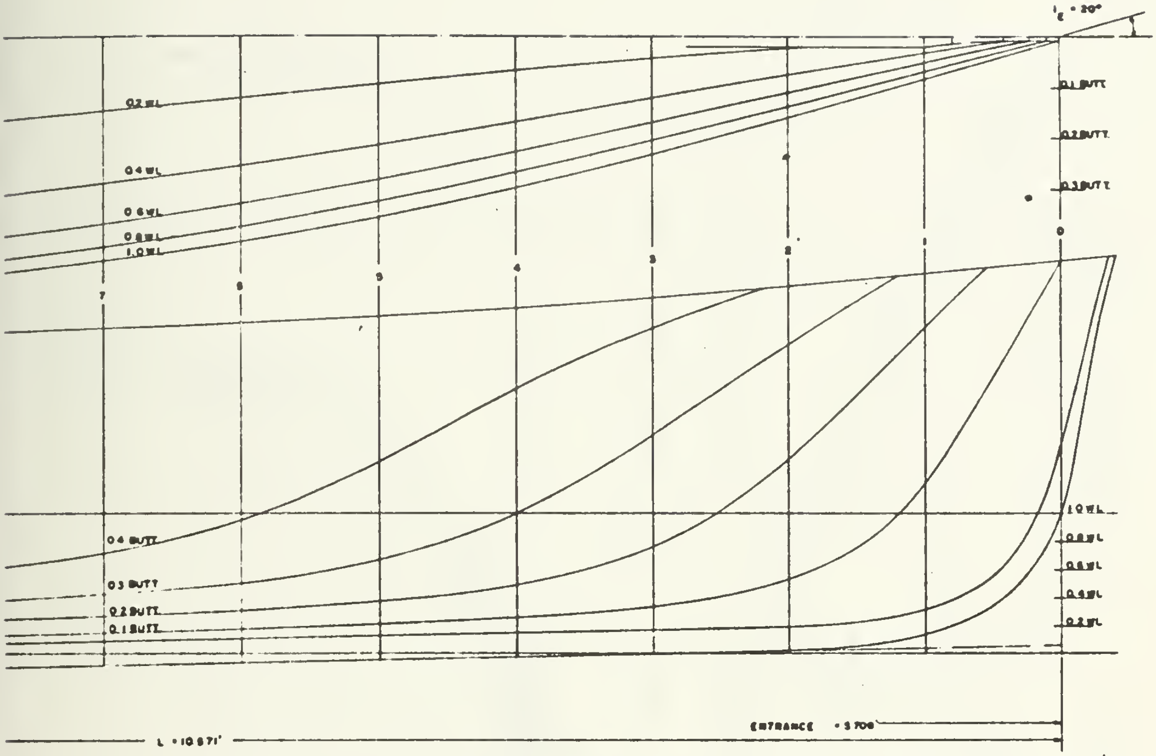
FIGURE 26.b.

TAKEN FROM REFERENCE 15



TAKEN FROM REFERENCE 15

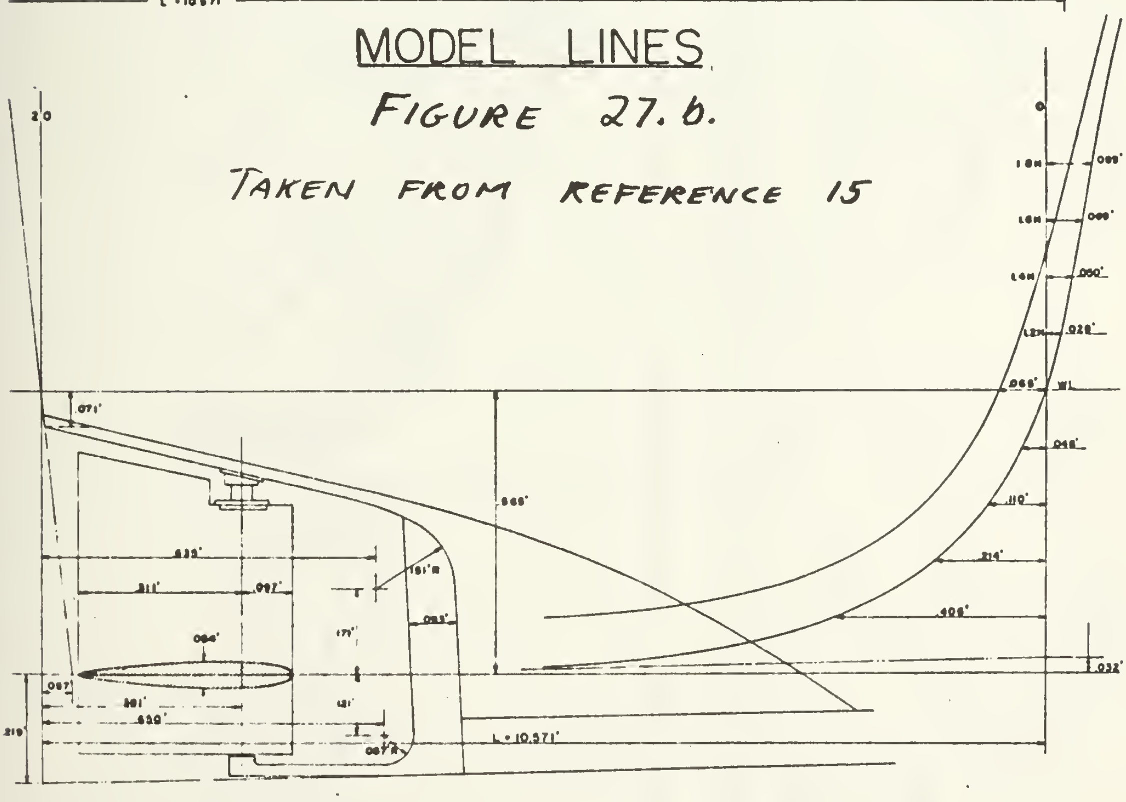
FIGURE 27. a.

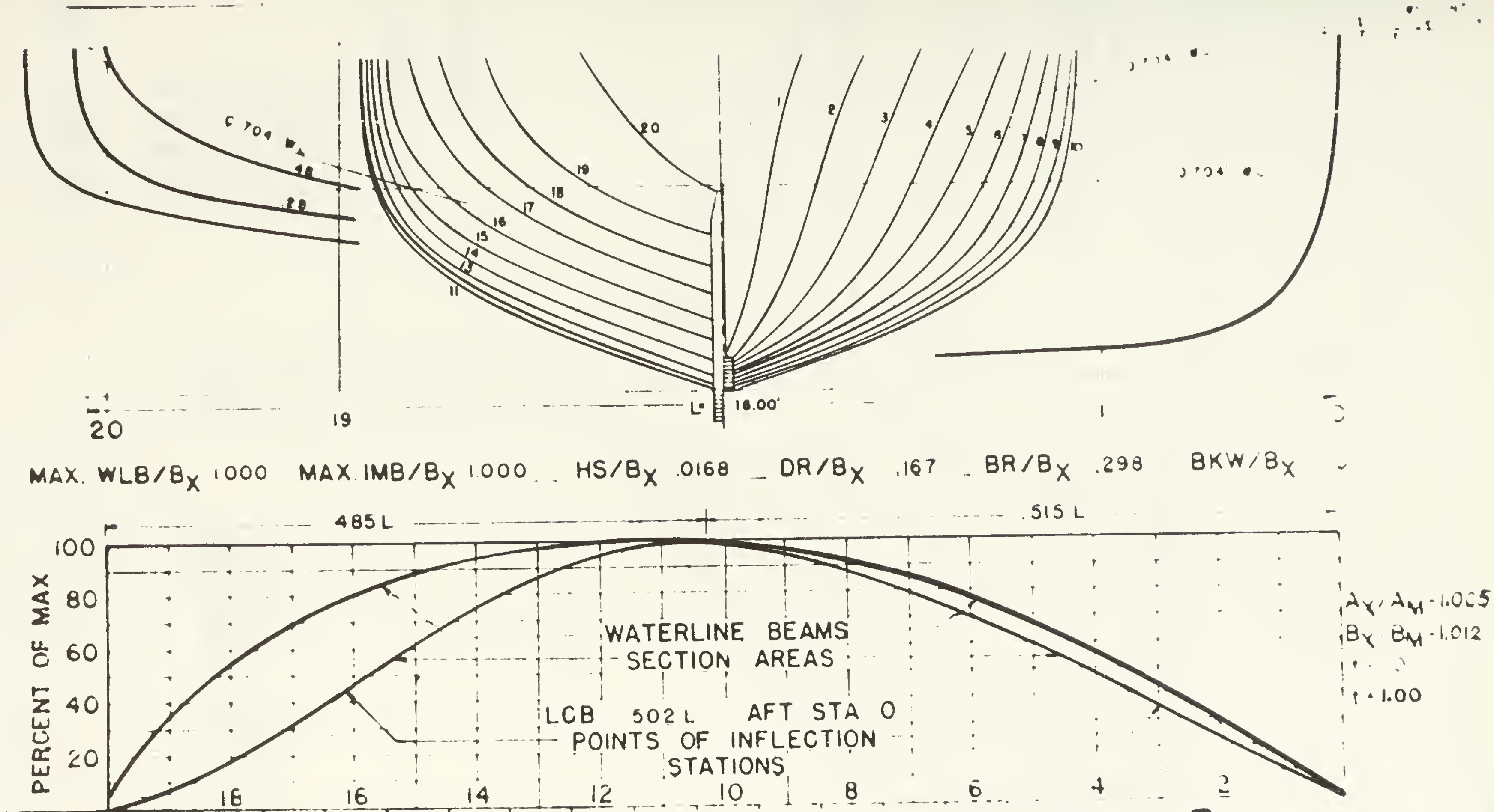


MODEL LINES

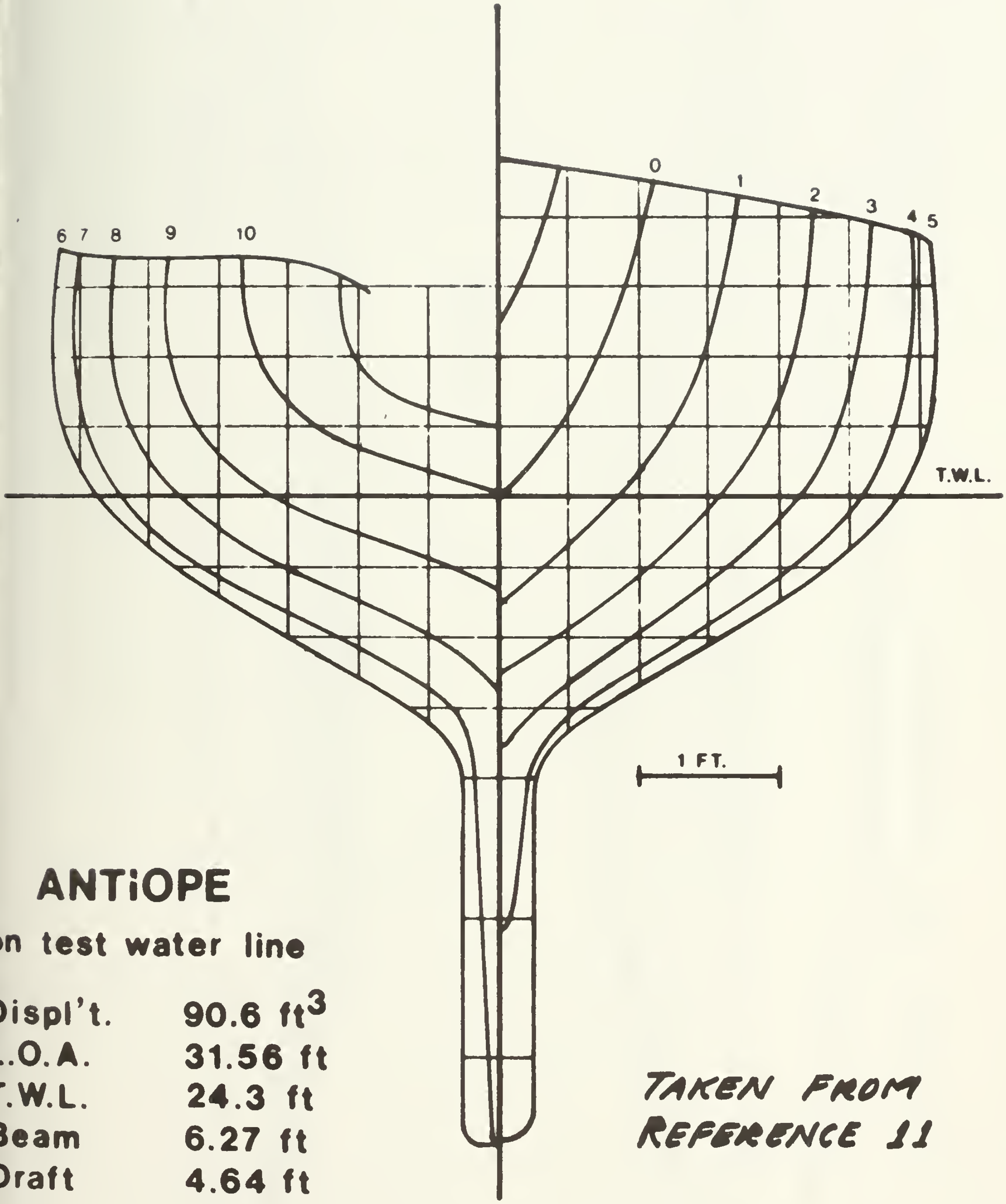
FIGURE 27. b.

TAKEN FROM REFERENCE 15





PATROL BOAT FROM REFERENCE 15 FIGURE 28



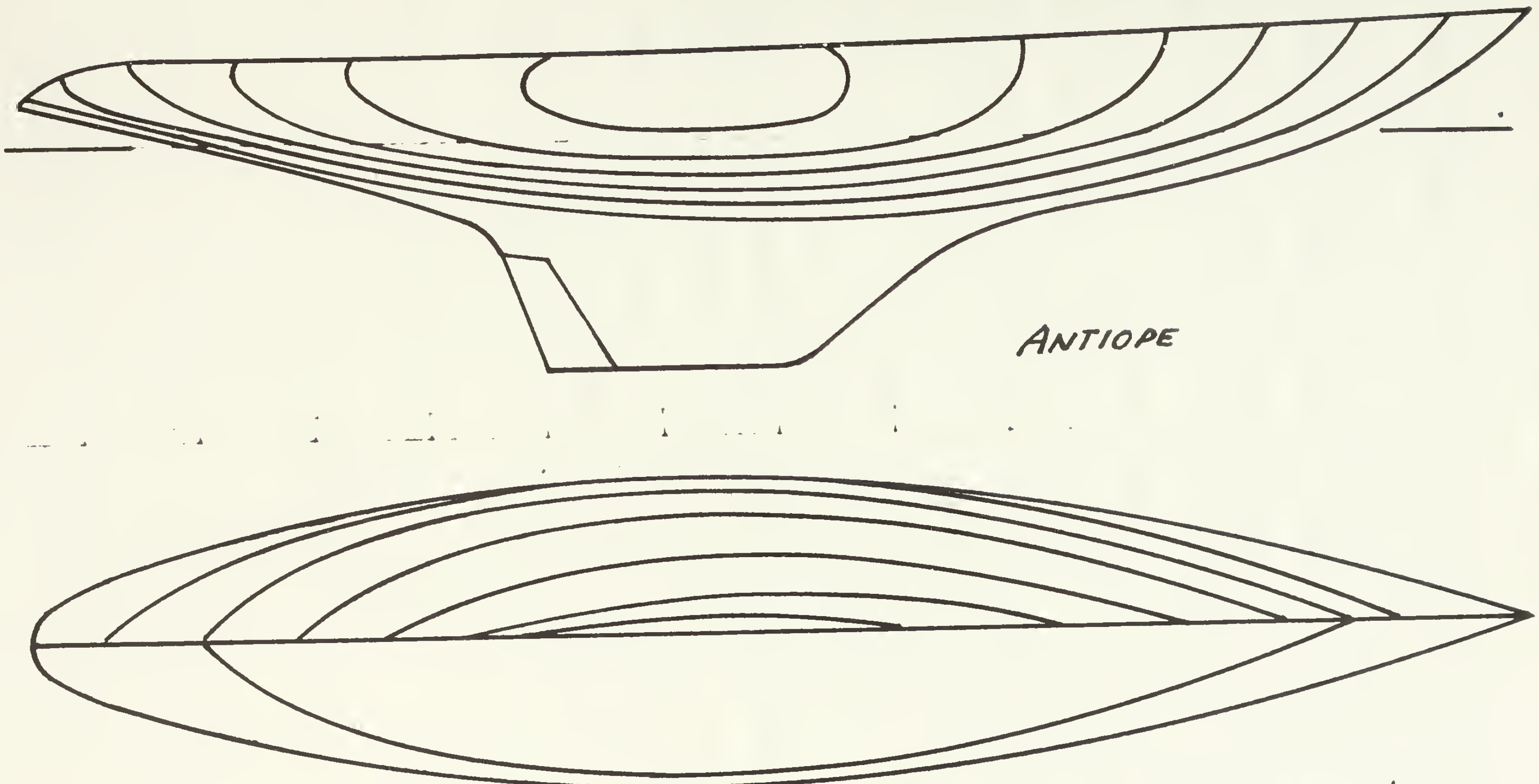
ANTiOPE

on test water line

Displ't.	**90.6 ft^3**
L.O.A.	**31.56 ft**
T.W.L.	**24.3 ft**
Beam	**6.27 ft**
Draft	**4.64 ft**

TAKEN FROM
REFERENCE 11

FIGURE 29. a.



ANTIOPE

ENLARGED FROM REFERENCE 11

FIGURE 29.b.

XIV. FORM DRAG RECOMMENDATIONS

Due to time limitations and to the relatively small contribution of form drag to the residuary drag at high speeds, a computer regression analysis was not utilized to derive formulae for F_o and F_1. The functional forms of F_o and F_1 were instead determined graphically and were limited to linear functions of C_p and B/T. Although these simple linear prediction formulae work surprisingly well, there are some data points plotted after the fact which are not well predicted. A regression analysis sampling all 315 residuary resistance coefficients at a $V/\sqrt{L}$ of .5 or less from reference 7 would surely pull in most of the wild points, particularly if higher order terms were made available for stepwise inclusion.

If a regression analysis were set up to fit prediction formulae to form drag, it would take only a little additional programming to include other higher order effects such as LCB location in the analysis.

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APPENDIX A

Program Used for Calculation of Weighted Variables and F_2 for the 1050 Ship-Speed Combinations

```
C
C   AN ANALYSIS OF RESICUARY DRAG
C
      DIMENSION XSLOP(11,11),ZSLCP(11,11),DA(11,11)
      DIMENSION YY(11,11),Y(11,11),AA(11,11),A(11),AM(11),G(11)
      DIMENSION CR(15,7)
      INTEGER VL,CVV,BC
      REAL M
      REAL LCB
      REAL LBP
      REAL LWL
      INTEGER WL
      INTEGER STA
      BUG=.5
      LWL=190.
      LBP=190.
      T=4.656
      B=17.461
C
      READ(5,1) ((YY(WL,STA),WL=1,9),STA=1,11)
    1 FORMAT(9F8.7)
C
      READ(5,39) ((CR(VL,CVV),VL=1,15),CVV=1,7)
   39 FORMAT (15F5.2)
C
      DO 35 STA=1,11
C
C   ADDITION OF WATERLINES .9 AND .7 TO THE TAYLCR CFFSETS
      DO 20 I=1,7
      WL=12-I
      YY(WL,STA)=YY(WL-2,STA)
   20 CONTINUE
      YY(3,STA)=YY(2,STA)
      YY(2,STA)=(YY(1,STA)+YY(3,STA))*0.5
      YY(4,STA)=(YY(3,STA)+YY(5,STA))*0.5
C
   35 CONTINUE
      CVV=1
   15 CONTINUE
C
C   PROPORTIONING OF FULL OFFSETS FRCM TAYLOR FRACTICNAL OFFSETS
      DO 7 STA=1,11
      DO 7 WL=1,11
      Y(WL,STA)=YY(WL,STA)*B*0.5
    7 CONTINUE
C
C   CALCULATION OF SLOPES AT EACH CFFSET REFERENCE PCINT
      DO 21 WL=1,11
      DO 21 STA=2,10
   21 XSLOP(WL,STA)=(Y(WL,STA+1)-Y(WL,STA-1))*05.0/LWL
      DO 22 STA=1,11
      DO 22 WL=2,1C
   22 ZSLOP(WL,STA)=(Y(WL+1,STA)-Y(WL-1,STA))*05.0/T
      DO 23 WL=1,11
```

```
   23 XSLOP(WL,1)=2.0*XSLCP(WL,2)-XSLCP(WL,3)
      DO 24 WL=1,11
   24 XSLCP(WL,11)=2.0*XSLOP(WL,1C)-XSLOP(WL,9)
      DO 25 STA=1,11
   25 ZSLCP(1,STA)=2.0*ZSLOP(2,STA)-ZSLOP(3,STA)
      DO 26 STA=1,11
   26 ZSLOP(11,STA)=2.0*ZSLCP(10,STA)-ZSLCP(9,STA)
C
      VL=1
      SL=0.5
      BUGR=BUG+.5
C
      WRITE (6,19) BUGR
   19 FORMAT ('1','******************************  SHIP NUMBER = ',F5.2,
     C'  ***************************************************')
C
      FR=0.0
      GO TO 34
C
    6 V=SL*SQRT(LWL)*1.689
C
C   CALCULATION OF EXPCNENT FOR WEIGHTING INCREMENTAL AREAS
      FR=32.2/(V**2)
C
C   CALCULATION OF FROUCE NUMBER
      F=V/((32.2*LWL)**.5)
C
   34 CONTINUE
      STA=1
    2 CONTINUE
C
C   INTEGRATION OF WEIGHTED INCREMENTAL AREAS OVER THE DRAFT FOR EACH SECTION
      DO 31 WL=1,11
   31 AA(WL,STA)=Y(WL,STA)*EXP(-FR*(WL-1)*T/10.0)*2.0
      EVNN=0.0
      ODDC=0.0
      DO 32 WL=2,10,2
   32 EVNN=EVNN+AA(WL,STA)
      DO 33 WL=3,9,2
   33 ODDD=ODDD+AA(WL,STA)
      A(STA)=(T/30.0)*(AA(1,STA)+4.0*EVNN+2.0*OCDC+AA(11,STA))
C
C   CALCULATION OF LCNGITUDINAL MCMENTS OF SECTIONAL AREAS
      AM(STA)=A(STA)*FLCAT(STA)
C
      IF(FR.GT.0.0) GO TO 18
C
C   INTEGRATION OF INCREMENTAL GIRTHS OVER EACH HALF SECTION
      DO 27 WL=1,11
   27 DA(WL,STA)=SQRT(1.0+(XSLOP(WL,STA))**2+(ZSLCP(WL,STA))**2)
      EVN=0.0
      ODDC=0.0
      DO 28 WL=2,10,2
   28 EVN=EVN+DA(WL,STA)
      DO 29 WL=3,9,2
```

```
   29 ODDC=ODDD+DA(WL,STA)
      G(STA)=(T/30.0)*(DA(1,STA)+4.0*EVN+2.0*ODDD+DA(11,STA))
C
   18 CONTINUE
C
      STA=STA+1
      IF (STA.LE.11) GC TC 2
C
C     INTEGRATION OF SECTIONAL AREAS OVER LENGTH FOR DISPLACEMENT
      ODD=0.0
      EVEN=0.0
      DO 3 STA=2,10,2
    3 EVEN=EVEN+A(STA)
      DO 4 STA=3,9,2
    4 ODD=ODD+A(STA)
      DISPL=(LBP/30.)*(A(1)+4.*EVEN+2.*ODC+A(11))
C
C     INTEGRATION OF MCMENTS CF AREAS CVER LENGTH FCR LCB
      AT=C.0
      AMT=0.0
      DO 9 STA=1,11
    9 AT=AT+A(STA)
      DO 5 STA=1,11
    5 AMT=AMT+AM(STA)
      LCB=(AMT/AT-6.)*(LBP/LWL)*.1
C
      M=LWL/(DISPL**.333333333)
C
C
      CP=DISPL/(A(6)*LWL)
      CPS=CP
C
      CV=DISPL/(LWL**3)
      CVST=CV*1000.0
C
      CM=A(6)/(B*T)
C
      CB=CM*CP
C
      IF (FR.LE.0.02) GC TO 14
C
C     F2 FOR CW BASED CN L**2
      CCR=CR(VL,CVV)
      CR5=CR(1,CVV)
      CR(VL,CVV)= 0.001*CR(VL,CVV)
      F2=(CR(VL,CVV) - CR(1,CVV)) * SL2 * (((LWL**3)/(DISPL))**2)
C
      PUNCH 44 , SL,CCR,CR5,CVST,CVT,CPS,CPN,SL2,BDR,F2
   44 FORMAT(F4.2,2X,F4.2,2X,F4.2,2X,F5.3,2X,F5.3,2X,F6.4,2X,F6.4,2X,
     CF6.4,2X,F4.2,2X,F6.2)
C
      WRITE (6,13) SL,F,DISPL,CP,CM,CB,CV,CCR,LCB,F2
   13 FORMAT('0',F4.2,2X,F5.3,3X,F6.C,3X,F9.4,3X,F9.4,3X,F9.4,3X,F9.6,3X
     C,F6.4,3X,F9.4,5X,F12.6)
C
```

```
      SL=SL+.05
      VL=VL+1
      IF (SL.LE.1.2) GO TO 6
      GO TO 36
C
   14 CONTINUE
C
C  INTEGRATION OF GIRTHS OVER LENGTH FOR WETTED SURFACE
      EVE=0.0
      OD=C.0
      DO 16 STA=2,10,2
   16 EVE=EVE+G(STA)
      DO 17 STA=3,9,2
   17 OD=CD+G(STA)
      S=0.06667*LBP*(G(1)+4.*EVE+2.*CC+G(11))
C
C  CORRECTION TO WETTEC SURFACE FCR SKEG
      S=S-T*LWL*(0.3372-0.438*CP)
C
      WS=S/SQRT(DISPL*LWL)
C
      CPN=CP
      DISP=DISPL
      CVT=CV*1000.0
      VR=CV
      SL2=S/(LWL**2)
      BDR=B/T
      FO=.0027+(CP-.5)*(.021+(BDR-2.25)*.C20333)
      FO=FO*0.001
      F1=14.+(BDR-2.25)*(4.+20.7*(CP-.5))
      F1=F1*0.001
      FF=VR*F1 + FO
C
      WRITE(6,11)LWL,B,T,DISPL,CP,CM
   11 FORMAT('-','LWL =',F7.2,5X,'B = ',F6.2,5X,'T = ',F6.2,5X,'DISPL =
     C ',F8.1,5X,'CP = ',F9.5,5X,'CM = ',F9.5)
C
      WRITE (6,12) CB,CV,S,WS
   12 FORMAT('-','CB = ',F9.5,5X,'CV = ',F9.5,5X,'S = ',F10.0,5X,'CS = '
     C,F9.4)
C
      WRITE(6,37) SL2,FF
   37 FORMAT('-','S/LWL**2 = ',F10.8,10X,'FO + F1*DISPL/(LWL**3) =',F10.
     C8)
C
      WRITE(6,8)
    8 FORMAT('-','SLR',5X,'F',5X,'CISPL *',5X,'CP *',8X,'CM *',9X,'CB *'
     C,9X,'CV *',5X,'  CCR   ',3X,'LCE *',10X,'F2')
C
      GO TO 6
C
   36 CONTINUE
      CVV=CVV+1
C  DIMENSIONS OF ADDITICNAL SHIPS TC BE CALCULATED
      BUG=BUG+1.0
```

```
C
      T=6.5851
      B=24.6941
      IF (BUG.LE.2.0) GC TO 15
      T=8.065
      B=30.244
      IF (BUG.LE.3.0) GC TO 15
      T=9.3127
      B=34.9227
      IF (BUG.LE.4.0) GC TO 15
      T=10.4119
      B=39.0447
      IF (BUG.LE.5.0) GC TO 15
      T=11.406
      B=42.77
      IF (BUG.LE.6.0) GC TO 15
      T=12.3196
      B=46.1984
      IF (BUG.LE.7.0) GC TO 15
C
      WRITE(6,100)
  100 FORMAT('1','END CF PROGRAM')
C
      STOP
      END

$ENTRY
```

APPENDIX B.1

Listing of Control Cards and Some Output Examples for One Regression Run

Example of first page of printout for $V/\sqrt{L} = 1.0$ run

```
TATISTICAL PACKAGE FOR THE SOCIAL SCIENCES SPSSH - RELEASE 6.02                    03/25/76

      SPACE ALLOCATION FOR THIS RUN..

          TOTAL AMOUNT REQUESTED                                      80000 BYTES

          DEFAULT TRANSPACE ALLOCATION                                10000 BYTES

             MAX NO OF TRANSFORMATIONS PERMITTED              100
             MAX NO OF RECODE VALUES                          400
             MAX NO OF ARITHM.OR LOG.OPERATIONS               800

          RESULTING WORKSPACE ALLOCATION                              70000 BYTES

                RUN NAME          MULTIPLE REGRESSION ANALYSIS OF THE TAYLOR SERIES
                FILE NAME         DATA FOR PREDICTION OF WAVE DRAG
                VARIABLE LIST     SLR,CR,CR5,CVST,CVT,CPS1,CP,SL2,BDR,F2
                VAR LABELS        SLR    SPEED LENGTH RATIO /
                                  CR     TAYLOR RESIDUARY DRAG COEFFICIENT TIMES 1000 /
                                  CR5  CR AT A SLR OF 0.5  /
                                  CVST    WEIGHTED VOLUMETRIC COEFFICIENT TIMES 1000 /
                                  CVT    ACTUAL VOLUMETRIC COEFFICIENT TIMES 1000 /
                                  CPS1    WEIGHTED PRISMATIC POLYNOMIAL TERM OF ORDER ONE /
                                  CP    ACTUAL PRISMATIC COEFFICIENT /
                                  SL2    RATIO OF WETTED SURFACE TO LENGTH SQUARED /
                                  BDR    BEAM TO DRAFT RATIO
                                  F2     CV STAR SQUARED TIMES CW BASED ON L  /
                INPUT FORMAT      FIXED (F4.2,2X,F4.2,2X,F4.2,2X,F5.3,2X,F5.3,2X,F6.4,2X,
                                  F6.4,2X,F6.4,2X,F4.2,2X,F6.2)

               ACCORDING TO YOUR INPUT FORMAT, VARIABLES ARE TO BE READ AS FOLLOWS

               VARIABLE  FORMAT  RECORD    COLUMNS

               SLR       F 4. 2       1      1-   4
               CR        F 4. 2       1      7-  10
               CR5       F 4. 2       1     13-  16
               CVST      F 5. 3       1     19-  23
               CVT       F 5. 3       1     26-  30
               CPS1      F 6. 4       1     33-  38
               CP        F 6. 4       1     41-  46
               SL2       F 6. 4       1     49-  54
               BDR       F 4. 2       1     57-  60
               F2        F 6. 2       1     63-  68

HE INPUT FORMAT PROVIDES FOR  10 VARIABLES.   10 WILL BE READ
T PROVIDES FOR   1 RECORDS ('CARDS') PER CASE.  A MAXIMUM OF   68 'COLUMNS' ARE USED ON A RECORD.

                COMPUTE           F3=F2*(CVST**(0.2))
                COMPUTE           CPSV=(CPS1-.48)/.27
                COMPUTE           CPSA=SIN(3.14*CPSV)
                COMPUTE           CPSB=SIN(3.14*CPSV*2.)
                COMPUTE           CPSC=SIN(3.14*CPSV*3.)
                COMPUTE           CPSD=SIN(3.14*CPSV*4.)
                COMPUTE           CPSE=SIN(3.14*CPSV*5.)
                N OF CASES        66
                REGRESSION        VARIABLES =F3,CPS1,
                                  CPSA,CPSB,CPSC,CPSD,CPSE  /
                                  REGRESSION=F3 WITH CPS1(1),
                                  CPSA(1),CPSB(1),CPSC(1),CPSD(1),CPSE(1),
                                  RESID=0 /
                STATISTICS      . ALL
```

Example first page of printout for $V/\sqrt{L}$ = 1.2 run

```
STATISTICAL PACKAGE FOR THE SOCIAL SCIENCES SPSSH - RELEASE 6.02                              03/25/76

          SPACE ALLOCATION FOR THIS RUN..

              TOTAL AMOUNT REQUESTED                                   80000 BYTES

              DEFAULT TRANSPACE ALLOCATION                             10000 BYTES

                 MAX NO OF TRANSFORMATIONS PERMITTED             100
                 MAX NO OF RECODE VALUES                         400
                 MAX NO OF ARITHM.OR LOG.OPERATIONS              800

              RESULTING WORKSPACE ALLOCATION                           70000 BYTES

                    RUN NAME       MULTIPLE REGRESSION ANALYSIS OF THE TAYLOR SERIES
                    FILE NAME      DATA FOR PREDICTION OF WAVE DRAG
                    VARIABLE LIST  SLR,CR,CR5,CVST,CVT,CPS1,CP,SL2,BDR,P2
                    VAR LABELS     SLR   SPEED LENGTH RATIO /
                                   CR    TAYLOR RESIDUARY DRAG COEFFICIENT TIMES 1000 /
                                   CR5  CR AT A SLR OF 0.5  /
                                   CVST   WEIGHTED VOLUMETRIC COEFFICIENT TIMES 1000 /
                                   CVT   ACTUAL VOLUMETRIC COEFFICIENT TIMES 1000 /
                                   CPS1   WEIGHTED PRISMATIC POLYNOMIAL TERM OF ORDER ONE /
                                   CP   ACTUAL PRISMATIC COEFFICIENT /
                                   SL2   RATIO OF WETTED SURFACE TO LENGTH SQUARED /
                                   BDR   BEAM TO DRAFT RATIO
                                   P2    CV STAR SQUARED TIMES CW BASED ON L  /
                    INPUT FORMAT   FIXED (F4.2,2X,F4.2,2X,F4.2,2X,F5.3,2X,F5.3,2X,F6.4,2X,
                                   F6.4,2X,F6.4,2X,F4.2,2X,F6.2)

                   ACCORDING TO YOUR INPUT FORMAT, VARIABLES ARE TO BE READ AS FOLLOWS

                   VARIABLE  FORMAT  RECORD    COLUMNS

                   SLR        F 4. 2       1      1-   4
                   CR         F 4. 2       1      7-  10
                   CR5        F 4. 2       1     13-  16
                   CVST       F 5. 3       1     19-  23
                   CVT        F 5. 3       1     26-  30
                   CPS1       F 6. 4       1     33-  38
                   CP         F 6. 4       1     41-  46
                   SL2        F 6. 4       1     49-  54
                   BDR        F 4. 2       1     57-  60
                   P2         F 6. 2       1     63-  68

THE INPUT FORMAT PROVIDES FOR  10 VARIABLES.   10 WILL BE READ
IT PROVIDES FOR  1 RECORDS ('CARDS') PER CASE.  A MAXIMUM OF   68 'COLUMNS' ARE USED ON A RECORD.

                    COMPUTE         P3=P2*(CVST**(0.2))
                    COMPUTE         CPSV=(CPS1-.43)/.27
                    COMPUTE         CPSA=SIN(3.14*CPSV)
                    COMPUTE         CPSB=SIN(3.14*CPSV*2.)
                    COMPUTE         CPSC=SIN(3.14*CPSV*3.)
                    COMPUTE         CPSD=SIN(3.14*CPSV*4.)
                    COMPUTE         CPSE=SIN(3.14*CPSV*5.)
                    N OF CASES      58
                    REGRESSION      VARIABLES =P3,CPS1,
                                    CPSA,CPSB,CPSC,CPSD,CPSE  /
                                    REGRESSION=P3 WITH CPS1(1),
                                    CPSA(1),CPSB(1),CPSC(1),CPSD(1),CPSE(1),
                                    RESID=0 /
                    STATISTICS      ALL
```

$V/\sqrt{L} = 1.2$

MULTIPLE REGRESSION ANALYSIS OF THE TAYLOR SERIES

FILE DATA (CREATION DATE = 03/25/76) FOR PREDICTION OF WAVE DRAG

VARIABLE	MEAN	STANDARD DEV	CASES
F3	63.4780	17.1256	58
CPS1	0.6006	0.0760	58
CPSA	0.6480	0.3104	58
CPSB	-0.0334	0.7113	58
CPSC	0.1843	0.6842	58
CPSD	0.0644	0.6223	58
CPSE	0.1026	0.7994	58

MULTIPLE REGRESSION ANALYSIS OF THE TAYLOR SERIES

FILE DATA (CREATION DATE = 03/25/76) FOR PREDICTION OF WAVE DRAG

CORRELATION COEFFICIENTS

A VALUE OF 99.00000 IS PRINTED
IF A COEFFICIENT CANNOT BE COMPUTED.

$V/\sqrt{L} = 1.2$

	F3	CPS1	CPSA	CESB	CPSC	CPSD	CPSE
F3	1.00000	0.05091	-0.82404	-0.39645	0.63766	-0.07692	0.30268
CPS1	0.05091	1.00000	0.45313	-0.79993	0.00418	-0.38396	-0.05120
CPSA	-0.82404	0.45313	1.00000	-0.08716	-0.64978	-0.03309	-0.29021
CESB	-0.39645	-0.79993	-0.08716	1.00000	0.00217	-0.04208	-0.07069
CPSC	0.63766	0.00413	-0.64978	0.00217	1.00000	-0.22777	-0.27663
CESD	-0.07692	-0.38396	-0.03309	-0.04208	-0.22777	1.00000	-0.41631
CPSE	0.30268	-0.05120	-0.29021	-0.07069	-0.27663	-0.41631	1.00000

MULTIPLE REGRESSION ANALYSIS OF THE TAYLOR SERIES 03/25/76 PAGE 5

FILE DATA (CREATION DATE = 03/25/76) FOR PREDICTION OF WAVE DRAG

* M U L T I P L E   R E G R E S S I O N * * * * * * * * * * * * * VARIABLE LIST 1
REGRESSION LIST 1

DEPENDENT VARIABLE.. F3

VARIABLE(S) ENTERED ON STEP NUMBER 1.. CPSA

MULTIPLE R	0.82404	ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F
R SQUARE	0.67903	REGRESSION	1.	11351.65222	11351.65222	118.47365
ADJUSTED R SQUARE	0.67330	RESIDUAL	56.	5365.68693	95.81584	
STANDARD ERROR	9.78856					

------------------ VARIABLES IN THE EQUATION ------------------

VARIABLE	B	BETA	STD ERROR B	F
CPSA	-45.46451	-0.82404	4.17697	118.474
(CONSTANT)	92.93783			

------------- VARIABLES NOT IN THE EQUATION -------------

VARIABLE	BETA IN	PARTIAL	TOLERANCE	F
CPS1	0.53393	0.84014	0.79467	131.971
CPSB	-0.47186	-0.82972	0.99240	121.526
CPSC	0.17691	0.23736	0.57778	3.288
CPSD	-0.10431	-0.18401	0.99890	1.928
CPSE	0.06937	0.11718	0.91578	0.766

* *

VARIABLE(S) ENTERED ON STEP NUMBER 2.. CPS1 WEIGHTED PRISMATIC POLYNOMIAL TERM OF OR

MULTIPLE R	0.95162	ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F
R SQUARE	0.90558	REGRESSION	2.	15138.95400	7569.47700	263.76403
ADJUSTED R SQUARE	0.90215	RESIDUAL	55.	1578.38515	28.69791	
STANDARD ERROR	5.35704					

------------------ VARIABLES IN THE EQUATION ------------------

VARIABLE	B	BETA	STD ERROR B	F
CPSA	-58.81309	-1.06598	2.56433	526.018
CPS1	120.23475	0.53393	10.47058	131.971
(CONSTANT)	29.33959			

------------- VARIABLES NOT IN THE EQUATION -------------

VARIABLE	BETA IN	PARTIAL	TOLERANCE	F
CPSB	-0.23517	-0.39379	0.26474	9.911
CPSC	-0.12291	-0.27293	0.46557	4.346
CPSD	0.11214	0.33200	0.82760	6.690
CPSE	0.02275	0.07055	0.90766	0.270

```
FILE    DATA      (CREATION DATE = 03/25/76)    FOR PREDICTION OF WAVE DRAG

* * * * * * * * * * * * * * * * * * * * * * M U L T I P L E   R E G R E S S I O N * * * * * * * * * * * * *   VARIABLE LIST  1
                                                                                                              REGRESSION LIST  1
DEPENDENT VARIABLE..     F3

VARIABLE(S) ENTERED ON STEP NUMBER  3..     CPSB

MULTIPLE R            0.95928                    ANALYSIS OF VARIANCE     DF      SUM OF SQUARES       MEAN SQUARE            F
R SQUARE              0.92022                    REGRESSION               3.        15383.71303        5127.90434      207.63453
ADJUSTED R SQUARE     0.91579                    RESIDUAL                54.         1333.62611          24.69678
STANDARD ERROR        4.96959

---------------- VARIABLES IN THE EQUATION ------------------      ------------- VARIABLES NOT IN THE EQUATION -------------

VARIABLE             B          BETA      STD ERROR B        F       VARIABLE       BETA IN     PARTIAL   TOLERANCE          F

CPSA         -54.31803      -0.98450        2.77448    383.287       CPSC          -0.01075    -0.01954     0.26352      0.020
CPS1          69.58906       0.30890       18.80619     13.692       CPSD          -0.00348    -0.00590     0.22917      0.002
CPSB          -5.66175      -0.23517        1.79846      9.911       CPSE           0.01782     0.06007     0.90628      0.192
(CONSTANT)    56.66786

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

VARIABLE(S) ENTERED ON STEP NUMBER  4..     CPSE

MULTIPLE R            0.95943                    ANALYSIS OF VARIANCE     DF      SUM OF SQUARES       MEAN SQUARE            F
R SQUARE              0.92051                    REGRESSION               4.        15389.52544        3847.13136      153.44360
ADJUSTED R SQUARE     0.91451                    RESIDUAL                53.         1328.81371          25.07196
STANDARD ERROR        5.00719

---------------- VARIABLES IN THE EQUATION ------------------      ------------- VARIABLES NOT IN THE EQUATION -------------

VARIABLE             B          BETA      STD ERROR B        F       VARIABLE       BETA IN     PARTIAL   TOLERANCE          F

CPSA         -54.01226      -0.97896        2.88129    351.409       CPSC           0.53216     0.19532     0.01071      2.062
CPS1          69.46102       0.30833       18.95074     13.435       CPSD           0.17984     0.12258     0.03693      0.793
CPSB          -5.63074      -0.23389        1.81346      9.641
CPSE           0.38180       0.01782        0.87146      0.192
(CONSTANT)    56.52649
```

MULTIPLE REGRESSION ANALYSIS OF THE TAYLOR SERIES 03/25/76 PAGE 7

FILE DATA (CREATION DATE = 03/25/76) FOR PREDICTION OF WAVE DRAG

* M U L T I P L E   R E G R E S S I O N * * * * * * * * * * * * * * VARIABLE LIST 1
REGRESSION LIST 1

DEPENDENT VARIABLE.. F3

VARIABLE(S) ENTERED ON STEP NUMBER 5.. CPSC

MULTIPLE R	0.96131	ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F
R SQUARE	0.92355	REGRESSION	5.	15439.21990	3087.84378	125.62815
ADJUSTED R SQUARE	0.91619	RESIDUAL	52.	1278.12025	24.57924	
STANDARD ERROR	4.95775					

------------------ VARIABLES IN THE EQUATION ------------------

VARIABLE	B	BETA	STD ERROR B	F
CPSA	-16.22610	-0.29409	26.46543	0.376
CPS1	-77.82784	-0.34547	104.26232	0.557
CPSB	-16.33437	-0.67847	7.66638	4.540
CPSZ	6.40300	0.29899	4.28054	2.238
CPSC	13.31920	0.53216	9.27441	2.062
(CONSTANT)	117.08125			

------------- VARIABLES NOT IN THE EQUATION -------------

VARIABLE	BETA IN	PARTIAL	TOLERANCE	F
CPSD	-0.19941	-0.07594	0.01109	0.296

* *

VARIABLE(S) ENTERED ON STEP NUMBER 6.. CPSD

MULTIPLE R	0.96124	ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F
R SQUARE	0.92399	REGRESSION	6.	15446.58929	2574.43155	103.32168
ADJUSTED R SQUARE	0.91504	RESIDUAL	51.	1270.74986	24.91666	
STANDARD ERROR	4.99166					

------------------ VARIABLES IN THE EQUATION ------------------

VARIABLE	B	BETA	STD ERROR B	F
CPSA	11.87599	0.21525	58.13605	0.042
CPS1	-248.39727	-1.10261	330.72049	0.564
CPSB	-29.94312	-1.24372	26.18527	1.308
CPSZ	7.94069	0.37067	5.15443	2.373
CPSC	21.07272	0.84195	17.04201	1.529
CPSD	-5.48740	-0.19941	10.08943	0.296
(CONSTANT)	199.83467			

------------- VARIABLES NOT IN THE EQUATION -------------

VARIABLE	BETA IN	PARTIAL	TOLERANCE	F

MAXIMUM STEP REACHED

T?LE REGRESSION ANALYSIS OF THE TAYLOR SERIES — 03/25/76 — PAGE 10

E DATA (CREATION DATE = 03/25/76) FOR PREDICTION OF WAVE DRAG

* M U L T I P L E   R E G R E S S I O N * * * * * * * * * * * * * * *

EDENT VARIABLE: F3 FROM VARIABLE LIST 1
REGRESSION LIST 1

N	OBSERVED F3	PREDICTED F3	RESIDUAL	PLOT OF STANDARDIZED RESIDUAL (-2.0 -1.0 0.0 1.0 2.0)
1	82.19550	84.96455	-2.769071	* I
2	87.00981	85.21678	1.793026	I*
3	93.21245	85.49003	7.732405	I *
4	91.02457	85.74049	5.284058	I *
5	83.20078	86.02934	-2.828582	* I
5	81.48373	84.17039	-2.686664	* I
7	82.57573	84.58971	-2.013988	*I
8	84.16908	84.96455	-.7954345	*
9	82.51404	85.40820	-2.894177	* I
0	85.99400	85.85475	.1392475	*
1	57.81540	60.79886	-2.983459	* I
2	58.93739	60.39572	-1.458332	*I
3	62.50374	59.93355	2.570189	I *
4	68.24979	59.41650	8.833281	I *
5	68.35806	58.78702	9.571038	I *
6	56.30518	58.05704	-1.751866	*I
7	55.72318	62.25871	-6.535548	* I
8	56.26572	61.69379	-5.428079	* I
9	57.18381	61.07109	-3.887284	* I
0	58.92725	60.39572	-1.468479	*I
1	62.78528	59.60905	3.176223	I *
2	58.36926	58.60193	-.2326729	*
3	43.85481	44.93106	-1.076247	*I
4	43.71724	44.78830	-1.071063	*I
5	47.15891	44.62337	2.535529	I*
6	49.12070	44.45654	4.664150	I *
7	52.91765	44.22424	8.693401	I *
8	36.43935	43.94568	-7.506338	* I
9	40.51698	45.38956	-4.872562	* I
0	41.99028	45.21204	-3.221763	* I
1	44.05937	45.01193	-.9525656	*I
2	45.86856	44.78830	1.080257	I*
3	48.14885	44.51935	3.629503	I *
4	40.38552	44.13998	-3.753355	* I
5	46.65015	48.49669	-1.846557	*I
6	47.17084	48.96924	-1.798404	*I
7	48.31050	49.59085	-1.280359	*I
8	48.34575	50.29916	-1.953417	*I
9	50.66368	51.09856	-.4348861	*
0	46.74394	52.22020	-5.476261	* I
1	52.65862	46.89206	5.766555	I *
2	50.21512	47.45030	2.764802	I *
3	47.43613	48.16522	-.7291036	*
4	50.97684	48.96924	2.007595	I*
5	53.21028	50.01367	3.196608	I *
6	50.71008	51.46852	-.7584471	*
7	73.38788	81.60811	-8.220250	* I
8	73.35895	81.60899	-8.250038	* I
9	73.51393	81.59581	-8.081897	* I
0	74.56857	81.56459	-6.996025	* I
1	77.35930	81.50571	-4.146430	* I
2	83.68127	81.39453	2.286718	I*
3	90.83012	81.51022	9.319894	I *
4	87.89235	81.56429	6.328051	I *
5	85.33984	81.60129	3.738543	I *
6	83.11327	81.60899	1.504259	I*
7	85.00876	81.57910	3.429640	I *
8	91.58952	81.47478	10.11473	I *

```
MULTIPLE REGRESSION ANALYSIS OF THE TAYLOR SERIES
FILE   DATA      (CREATION DATE = 03/25/76)
FOR PREDICTION OF WAVE DRAG
* * * * * * *  PLOT:  STANDARDIZED RESIDUAL (DOWN) --
PREDICTED STANDARDIZED DEPENDENT VARIABLE (ACROSS)  *
DEPENDENT VARIABLE:  F3            VARIABLE LIST   1
                                 REGRESSION LIST   1

        -2.0      -1.0       0.0       1.0       2.0
       .YX+---------+---------+---------+---------+XY.
        Y                    I                    Y
        X                    I                    X
   2.0  +                    I                    +
        I                    I                    I
        I                    I                    I
        I                    I                    I
        I                    I                    I
        I                    I                    I
        I                    I                    I
        I                    I                    I
        I                    I                    I
        I                    I                    I
   1.0  +                    I                    +
        I                    I                    I
        I                    I                    I
        I                    I                    I
        I                  * I         *          I
        I         *       *  I         * *        I
        I                    I         *          I
        I         **         I           *        I
        I         * **    2  I         2          I
        I         2  *       I        ** *        I
  -0.0  +------------*-2---*--I-----------2---------+
        I         3  *:   *2 I          *         I
        I         2       **I         **3         I
        I         *   *    *I                     I
        I         *        *I          *          I
        I                    I         3          I
        I                    I                    I
        I                    I                    I
        I                    I                    I
        I                    I                    I
  -1.0  +                    I                    +
        I                    I                    I
        I                    I                    I
        I                    I                    I
        I                    I                    I
        I                    I                    I
        I                    I                    I
        I                    I                    I
        I                    I                    I
        I                    I                    I
  -2.0  +                    I                    +
        X                    I                    X
        Y                    I                    Y
       .YX+---------+---------+---------+---------+XY.
        -2.0      -1.0       0.0       1.0       2.0

ROWS,COLUMNS Y:  VALUES OUTSIDE (-3.0,3.0)
ROWS,COLUMNS X:  VALUES IN (-3.0,-2.05) OR (2.05,3.0)
```

APPENDIX B.2

Listing of the Resulting Regression Coefficients for Each of 14 Runs

Coefficients are listed in column "B"

MULTIPLE REGRESSION ANALYSIS OF THE TAYLOR SERIES $V/\sqrt{L} = .6$ 03/25/76

FILE DATA (CREATION DATE = 03/25/76) FOR PREDICTION OF WAVE DRAG

* M U L T I P L E R E G R E S S I O N * * *

DEPENDENT VARIABLE.. F3

SUMMARY TABLE

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B	BETA
CPSE	0.07618	0.00580	0.00580	-0.07618	-0.07479	-0.20937
CPSA	0.09412	0.00886	0.00305	-0.00649	-0.08869	-0.09294
CPSC	0.10611	0.01126	0.00240	0.02983	-0.01572	-0.03936
CPSH	0.11519	0.01327	0.00201	0.02174	0.19077	0.47496
CPSI	0.11993	0.01438	0.00111	0.01463	1.93905	0.52278
CPSD	0.14302	0.02045	0.00607	-0.05547	0.08268	0.23254
(CONSTANT)					-0.51690	

MULTIPLE REGRESSION ANALYSIS OF THE TAYLOR SERIES $V/\sqrt{L} = .65$ 03/25/76

FILE DATA (CREATION DATE = 03/25/76) FOR PREDICTION OF WAVE DRAG

* M U L T I P L E R E G R E S S I O N * * *

DEPENDENT VARIABLE.. F3

SUMMARY TABLE

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B	BETA
CPSA	0.54117	0.29286	0.29286	-0.54117	-3.27341	-1.51822
CPS1	0.72836	0.53050	0.23764	0.52802	14.03419	1.76759
CPSC	0.74930	0.56146	0.03095	0.36051	-0.76045	-0.88398
CPSE	0.75531	0.57050	0.00904	0.37019	-0.35775	-0.52846
CPSD	0.76215	0.58088	0.01038	-0.18704	0.54538	0.74302
CPSB	0.78913	0.62273	0.04185	-0.40798	0.91663	1.17388
(CONSTANT)					-5.22966	

MULTIPLE REGRESSION ANALYSIS OF THE TAYLOR SERIES $V/\sqrt{L} = .7$ 03/25/76

FILE DATA (CREATION DATE = 03/25/76) FOR PREDICTION OF WAVE DRAG

* M U L T I P L E R E G R E S S I O N * * *

DEPENDENT VARIABLE.. F3

SUMMARY TABLE

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B	BETA
CPSA	0.65038	0.42299	0.42299	-0.65038	-6.37264	-1.27270
CPS1	0.87447	0.76469	0.34170	0.55847	27.60686	1.52472
CPSC	0.88540	0.78393	0.01924	0.52037	-1.04508	-0.53049
CPSB	0.88604	0.78507	0.00114	-0.46164	1.47182	0.82819
CPSD	0.89146	0.79470	0.00963	-0.29074	0.76934	0.44184
CPSF	0.89433	0.79982	0.00513	0.41229	-0.32664	-0.22459
(CONSTANT)					-10.17655	

MULTIPLE REGRESSION ANALYSIS OF THE TAYLOR SERIES $V/\sqrt{L} = .75$ 03/25/76

FILE DATA (CREATION DATE = 03/25/76) FOR PREDICTION OF WAVE DRAG

* - * M U L T I P L E R E G R E S S I O N * * *

DEPENDENT VARIABLE.. F3

SUMMARY TABLE

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B	BETA
CPSA	0.61209	0.37466	0.37466	-0.61209	-1.35837	-0.14162
CPS1	0.90492	0.81887	0.44421	0.55944	18.27273	0.51877
CPSE	0.91037	0.82877	0.00990	0.38399	1.03527	0.36490
CPSC	0.91711	0.84108	0.01231	0.58822	1.82182	0.46553
CPSD	0.91721	0.84127	0.00019	-0.33725	-0.17683	-0.04944
CPSB	0.91725	0.84135	0.00008	-0.51137	-0.23726	-0.06615
(CONSTANT)					-6.61240	

MULTIPLE REGRESSION ANALYSIS OF THE TAYLOR SERIES $V/\sqrt{L} = .8$ 03/25/76

FILE DATA (CREATION DATE = 03/25/76) FOR PREDICTION OF WAVE DRAG

* M U L T I P L E R E G R E S S I O N * * *

DEPENDENT VARIABLE.. F3

SUMMARY TABLE

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B	BETA
CPSA	0.65170	0.42471	0.42471	-0.65170	10.24238	0.61599
CPS1	0.87782	0.77057	0.34586	0.43557	-76.56588	-1.22618
CPSE	0.88097	0.77611	0.00554	0.35629	8.10078	0.62298
CPSC	0.88581	0.78465	0.00854	0.63144	7.09660	1.04472
CPSB	0.88640	0.78571	0.00106	-0.44727	-9.23029	-1.44014
CPSD	0.90173	0.81313	0.02741	-0.31417	-4.63390	-0.70941
(CONSTANT)					45.08026	

MULTIPLE REGRESSION ANALYSIS OF THE TAYLOR SERIES $V/\sqrt{L} = .85$ 03/25/76

FILE DATA (CREATION DATE = 03/25/76) FOR PREDICTION OF WAVE DRAG

* M U L T I P L E R E G R E S S I O N * * *

DEPENDENT VARIABLE.. F3

SUMMARY TABLE

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B	BETA
CPSA	0.56408	0.31819	0.31819	-0.56408	20.11981	0.91068
CPS1	0.86117	0.74162	0.42343	0.48301	-145.15875	-1.72953
CPSE	0.86455	0.74745	0.00583	0.32095	4.26392	0.63236
CPSB	0.86581	0.74963	0.00217	-0.54071	-16.67177	-1.92125
CPSD	0.87005	0.75698	0.00736	-0.27989	-7.38166	-0.81758
CPSC	0.88652	0.78592	0.02893	0.56355	10.78237	1.17888
(CONSTANT)					82.66532	

MULTIPLE REGRESSION ANALYSIS OF THE TAYLOR SERIES $V/\sqrt{L} = .9$ 03/25/76

FILE DATA (CREATION DATE = 03/25/76) FOR PREDICTION OF WAVE DRAG

* M U L T I P L E R E G R E S S I O N * * * *

DEPENDENT VARIABLE.. F3

SUMMARY TABLE

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B	BETA
CPSB	0.75640	0.57214	0.57214	-0.75640	-18.24381	-1.48717
CPSC	0.83856	0.70318	0.13105	0.37675	10.29975	0.80006
CPSD	0.87676	0.76870	0.06552	-0.31027	-6.99576	-0.53849
CPSE	0.89897	0.80815	0.03945	0.29350	3.84373	0.39982
CPS1	0.89920	0.80856	0.00041	0.72427	-111.64117	-0.94679
CPSA	0.90125	0.81225	0.00369	-0.27403	19.80405	0.64507
(CONSTANT)					67.39003	

MULTIPLE REGRESSION ANALYSIS OF THE TAYLOR SERIES $V/\sqrt{L} = .95$ 03/25/76

FILE DATA (CREATION DATE = 03/25/76) FOR PREDICTION OF WAVE DRAG

* M U L T I P L E R E G R E S S I O N * * * *

DEPENDENT VARIABLE.. F3

SUMMARY TABLE

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B	BETA
CPSI	0.85932	0.73842	0.73842	0.85932	-62.09348	-0.29525
CPSA	0.93659	0.87721	0.13879	-0.77741	24.76539	0.45512
CPSH	0.94260	0.88850	0.01129	-0.84944	-22.85361	-1.05103
CPSE	0.94331	0.88983	0.00133	0.13627	4.75583	0.27314
CPSC	0.94387	0.89089	0.00106	0.25557	13.09748	0.56879
CPSD	0.94554	0.89406	0.00317	-0.33923	-7.53123	-0.31726
(CONSTANT)					40.86973	

MULTIPLE REGRESSION ANALYSIS OF THE TAYLOR SERIES $V/\sqrt{L} = 1.0$ 03/25/76

FILE DATA (CREATION DATE = 03/25/76) FOR PREDICTION OF WAVE DRAG

* M U L T I P L E R E G R E S S I O N * * *

DEPENDENT VARIABLE.. F3

SUMMARY TABLE

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B	BETA
CPS1	0.88002	0.77443	0.77443	0.88002	259.93265	0.83008
CPSA	0.96248	0.92636	0.15193	0.02156	-19.08670	-0.24484
CPSB	0.96507	0.93136	0.00500	-0.85925	-6.66759	-0.20531
CPSE	0.96556	0.93231	0.00096	0.07614	2.42051	0.09209
CPSC	0.96571	0.93259	0.00028	0.21634	3.81046	0.11078
(CONSTANT)					-113.43612	

MULTIPLE REGRESSION ANALYSIS OF THE TAYLOR SERIES $\quad V/\sqrt{L} = 1.05$ $\quad$ 03/25/76

FILE DATA (CREATION DATE = 03/25/76) FOR PREDICTION OF WAVE DRAG

* M U L T I P L E R E G R E S S I O N * * *

DEPENDENT VARIABLE.. F3

SUMMARY TABLE

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B	BETA
CPSI	0.87359	0.76315	0.76315	0.87359	271.06878	0.77260
CPSA	0.97968	0.95977	0.19661	-0.05083	-21.26074	-0.24204
CPSP	0.98255	0.96540	0.00563	-0.87116	-9.23948	-0.25206
CPSE	0.98292	0.96612	0.00073	0.14248	3.40950	0.11064
CPSC	0.98312	0.96653	0.00041	0.28703	5.98221	0.15304
(CONSTANT)					-112.17450	

MULTIPLE REGRESSION ANALYSIS OF THE TAYLOR SERIES $V/\sqrt{L} = 1.1$ 03/25/76

FILE DATA (CREATION DATE = 03/25/76) FOR PREDICTION OF WAVE DRAG

* M U L T I P L E R E G R E S S I O N * * * *

DEPENDENT VARIABLE.. F3

SUMMARY TABLE

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B	BETA
CPSB	0.85267	0.72705	0.72705	-0.85267	-21.31415	-0.64242
CPSC	0.93717	0.87830	0.15125	0.38768	12.80481	0.36903
CPSD	0.98281	0.96592	0.08762	-0.34205	-4.60569	-0.12257
CPSE	0.98819	0.97652	0.01060	0.17181	5.04010	0.17753
CPS1	0.98866	0.97745	0.00094	0.79376	80.34268	0.25734
CPSA	0.98867	0.97746	0.00001	-0.18598	-4.13889	-0.05342
(CONSTANT)					-4.61396	

MULTIPLE REGRESSION ANALYSIS OF THE TAYLOR SERIES $V/\sqrt{L} = 1.15$ 03/25/76

FILE DATA (CREATION DATE = 03/25/76) FOR PREDICTION OF WAVE DRAG

* M U L T I P L E R E G R E S S I O N * * *

DEPENDENT VARIABLE.. F3

SUMMARY TABLE

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B	BETA
CPSB	0.73345	0.53794	0.53794	-0.73345	-32.90787	-1.21548
CPSA	0.91722	0.84130	0.30336	-0.48332	20.35142	0.32508
CPS1	0.97561	0.95181	0.11051	0.53982	-165.74835	-0.65249
CPSE	0.97631	0.95318	0.00136	0.25989	8.56621	0.36249
CPSC	0.97761	0.95572	0.00255	0.53199	22.44191	0.79520
CPSD	0.97796	0.95640	0.00068	-0.25157	-6.98242	-0.22663
(CONSTANT)					132.55430	

MULTIPLE REGRESSION ANALYSIS OF THE TAYLOR SERIES $V/\sqrt{L} = 1.2$ 03/25/76

FILE DATA (CREATION DATE = 03/25/76) FOR PREDICTION OF WAVE DRAG

* M U L T I P L E R E G R E S S I O N * * *

DEPENDENT VARIABLE.. F3

SUMMARY TABLE

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B	BETA
CPSA	0.82404	0.67903	0.67903	-0.82404	11.87589	0.21525
CPS1	0.95162	0.90558	0.22655	0.05091	-248.39727	-1.10261
CPSB	0.95928	0.92022	0.01464	-0.39645	-29.94312	-1.24372
CPSE	0.95943	0.92051	0.00029	0.30268	7.94069	0.37067
CPSC	0.96101	0.92355	0.00303	0.63766	21.07272	0.84195
CPSD	0.96124	0.92399	0.00044	-0.07692	-5.48740	-0.19941
(CONSTANT					199.63467	

APPENDIX B.3

Tables of F_3 Calculated Using the Regression Coefficients

$V/\sqrt{L} = .6$

```
CP * = 0.4800     F3 =  0.1040
CP * = 0.4850     F3 =  0.1094
CP * = 0.4900     F3 =  0.1150
CP * = 0.4950     F3 =  0.1208
CP * = 0.5000     F3 =  0.1270
CP * = 0.5050     F3 =  0.1335
CP * = 0.5100     F3 =  0.1403
CP * = 0.5150     F3 =  0.1473
CP * = 0.5200     F3 =  0.1543
CP * = 0.5250     F3 =  0.1609
CP * = 0.5300     F3 =  0.1670
CP * = 0.5350     F3 =  0.1722
CP * = 0.5400     F3 =  0.1762
CP * = 0.5450     F3 =  0.1788
CP * = 0.5500     F3 =  0.1799
CP * = 0.5550     F3 =  0.1792
CP * = 0.5600     F3 =  0.1770
CP * = 0.5650     F3 =  0.1733
CP * = 0.5700     F3 =  0.1683
CP * = 0.5750     F3 =  0.1625
CP * = 0.5800     F3 =  0.1561
CP * = 0.5850     F3 =  0.1498
CP * = 0.5900     F3 =  0.1438
CP * = 0.5950     F3 =  0.1387
CP * = 0.6000     F3 =  0.1349
CP * = 0.6050     F3 =  0.1325
CP * = 0.6100     F3 =  0.1317
CP * = 0.6150     F3 =  0.1326
CP * = 0.6200     F3 =  0.1350
CP * = 0.6250     F3 =  0.1388
CP * = 0.6300     F3 =  0.1434
CP * = 0.6350     F3 =  0.1485
CP * = 0.6400     F3 =  0.1537
CP * = 0.6450     F3 =  0.1583
CP * = 0.6500     F3 =  0.1620
CP * = 0.6550     F3 =  0.1643
CP * = 0.6600     F3 =  0.1651
CP * = 0.6650     F3 =  0.1642
CP * = 0.6700     F3 =  0.1616
CP * = 0.6750     F3 =  0.1575
CP * = 0.6800     F3 =  0.1523
CP * = 0.6850     F3 =  0.1465
CP * = 0.6900     F3 =  0.1407
CP * = 0.6950     F3 =  0.1355
CP * = 0.7000     F3 =  0.1316
```

$V/\sqrt{L} = .65$

CP * =	0.4800	F3 =	0.3786
CP * =	0.4850	F3 =	0.3478
CP * =	0.4900	F3 =	0.3182
CP * =	0.4950	F3 =	0.2911
CP * =	0.5000	F3 =	0.2674
CP * =	0.5050	F3 =	0.2476
CP * =	0.5100	F3 =	0.2321
CP * =	0.5150	F3 =	0.2207
CP * =	0.5200	F3 =	0.2130
CP * =	0.5250	F3 =	0.2081
CP * =	0.5300	F3 =	0.2052
CP * =	0.5350	F3 =	0.2030
CP * =	0.5400	F3 =	0.2004
CP * =	0.5450	F3 =	0.1965
CP * =	0.5500	F3 =	0.1905
CP * =	0.5550	F3 =	0.1819
CP * =	0.5600	F3 =	0.1707
CP * =	0.5650	F3 =	0.1572
CP * =	0.5700	F3 =	0.1423
CP * =	0.5750	F3 =	0.1269
CP * =	0.5800	F3 =	0.1124
CP * =	0.5850	F3 =	0.1002
CP * =	0.5900	F3 =	0.0917
CP * =	0.5950	F3 =	0.0880
CP * =	0.6000	F3 =	0.0901
CP * =	0.6050	F3 =	0.0985
CP * =	0.6100	F3 =	0.1131
CP * =	0.6150	F3 =	0.1333
CP * =	0.6200	F3 =	0.1581
CP * =	0.6250	F3 =	0.1858
CP * =	0.6300	F3 =	0.2145
CP * =	0.6350	F3 =	0.2422
CP * =	0.6400	F3 =	0.2665
CP * =	0.6450	F3 =	0.2856
CP * =	0.6500	F3 =	0.2978
CP * =	0.6550	F3 =	0.3021
CP * =	0.6600	F3 =	0.2981
CP * =	0.6650	F3 =	0.2863
CP * =	0.6700	F3 =	0.2679
CP * =	0.6750	F3 =	0.2451
CP * =	0.6800	F3 =	0.2209
CP * =	0.6850	F3 =	0.1985
CP * =	0.6900	F3 =	0.1820
CP * =	0.6950	F3 =	0.1753
CP * =	0.7000	F3 =	0.1823

$V/\sqrt{L} = .7$

CP * =	0.4800	F3 =	0.7725
CP * =	0.4850	F3 =	0.7325
CP * =	0.4900	F3 =	0.6931
CP * =	0.4950	F3 =	0.6550
CP * =	0.5000	F3 =	0.6187
CP * =	0.5050	F3 =	0.5846
CP * =	0.5100	F3 =	0.5526
CP * =	0.5150	F3 =	0.5227
CP * =	0.5200	F3 =	0.4946
CP * =	0.5250	F3 =	0.4678
CP * =	0.5300	F3 =	0.4417
CP * =	0.5350	F3 =	0.4159
CP * =	0.5400	F3 =	0.3900
CP * =	0.5450	F3 =	0.3636
CP * =	0.5500	F3 =	0.3367
CP * =	0.5550	F3 =	0.3095
CP * =	0.5600	F3 =	0.2827
CP * =	0.5650	F3 =	0.2570
CP * =	0.5700	F3 =	0.2334
CP * =	0.5750	F3 =	0.2133
CP * =	0.5800	F3 =	0.1979
CP * =	0.5850	F3 =	0.1884
CP * =	0.5900	F3 =	0.1859
CP * =	0.5950	F3 =	0.1911
CP * =	0.6000	F3 =	0.2042
CP * =	0.6050	F3 =	0.2252
CP * =	0.6100	F3 =	0.2534
CP * =	0.6150	F3 =	0.2876
CP * =	0.6200	F3 =	0.3261
CP * =	0.6250	F3 =	0.3669
CP * =	0.6300	F3 =	0.4079
CP * =	0.6350	F3 =	0.4467
CP * =	0.6400	F3 =	0.4813
CP * =	0.6450	F3 =	0.5099
CP * =	0.6500	F3 =	0.5314
CP * =	0.6550	F3 =	0.5453
CP * =	0.6600	F3 =	0.5520
CP * =	0.6650	F3 =	0.5527
CP * =	0.6700	F3 =	0.5496
CP * =	0.6750	F3 =	0.5457
CP * =	0.6800	F3 =	0.5449
CP * =	0.6850	F3 =	0.5514
CP * =	0.6900	F3 =	0.5699
CP * =	0.6950	F3 =	0.6049
CP * =	0.7000	F3 =	0.6606

$V/\sqrt{L} = .75$

CP * =	0.4800		F3 =	0.5423
CP * =	0.4850		F3 =	0.6824
CP * =	0.4900		F3 =	0.8144
CP * =	0.4950		F3 =	0.9311
CP * =	0.5000		F3 =	1.0261
CP * =	0.5050		F3 =	1.0947
CP * =	0.5100		F3 =	1.1339
CP * =	0.5150		F3 =	1.1427
CP * =	0.5200		F3 =	1.1224
CP * =	0.5250		F3 =	1.0760
CP * =	0.5300		F3 =	1.0081
CP * =	0.5350		F3 =	0.9245
CP * =	0.5400		F3 =	0.8320
CP * =	0.5450		F3 =	0.7372
CP * =	0.5500		F3 =	0.6467
CP * =	0.5550		F3 =	0.5662
CP * =	0.5600		F3 =	0.5001
CP * =	0.5650		F3 =	0.4514
CP * =	0.5700		F3 =	0.4216
CP * =	0.5750		F3 =	0.4103
CP * =	0.5800		F3 =	0.4158
CP * =	0.5850		F3 =	0.4351
CP * =	0.5900		F3 =	0.4644
CP * =	0.5950		F3 =	0.4995
CP * =	0.6000		F3 =	0.5361
CP * =	0.6050		F3 =	0.5706
CP * =	0.6100		F3 =	0.6002
CP * =	0.6150		F3 =	0.6232
CP * =	0.6200		F3 =	0.6395
CP * =	0.6250		F3 =	0.6501
CP * =	0.6300		F3 =	0.6575
CP * =	0.6350		F3 =	0.6654
CP * =	0.6400		F3 =	0.6779
CP * =	0.6450		F3 =	0.6997
CP * =	0.6500		F3 =	0.7352
CP * =	0.6550		F3 =	0.7881
CP * =	0.6600		F3 =	0.8610
CP * =	0.6650		F3 =	0.9553
CP * =	0.6700		F3 =	1.0705
CP * =	0.6750		F3 =	1.2041
CP * =	0.6800		F3 =	1.3522
CP * =	0.6850		F3 =	1.5093
CP * =	0.6900		F3 =	1.6684
CP * =	0.6950		F3 =	1.8222
CP * =	0.7000		F3 =	1.9627

$V/\sqrt{L} = .8$

CP * =	0.4800		F3 =	2.0925
CP * =	0.4850		F3 =	2.1409
CP * =	0.4900		F3 =	2.1787
CP * =	0.4950		F3 =	2.1964
CP * =	0.5000		F3 =	2.1865
CP * =	0.5050		F3 =	2.1441
CP * =	0.5100		F3 =	2.0676
CP * =	0.5150		F3 =	1.9588
CP * =	0.5200		F3 =	1.8227
CP * =	0.5250		F3 =	1.6670
CP * =	0.5300		F3 =	1.5017
CP * =	0.5350		F3 =	1.3377
CP * =	0.5400		F3 =	1.1859
CP * =	0.5450		F3 =	1.0565
CP * =	0.5500		F3 =	0.9573
CP * =	0.5550		F3 =	0.9936
CP * =	0.5600		F3 =	0.8670
CP * =	0.5650		F3 =	0.8759
CP * =	0.5700		F3 =	0.9149
CP * =	0.5750		F3 =	0.9759
CP * =	0.5800		F3 =	1.0485
CP * =	0.5850		F3 =	1.1211
CP * =	0.5900		F3 =	1.1823
CP * =	0.5950		F3 =	1.2219
CP * =	0.6000		F3 =	1.2323
CP * =	0.6050		F3 =	1.2092
CP * =	0.6100		F3 =	1.1528
CP * =	0.6150		F3 =	1.0673
CP * =	0.6200		F3 =	0.9618
CP * =	0.6250		F3 =	0.8490
CP * =	0.6300		F3 =	0.7447
CP * =	0.6350		F3 =	0.6661
CP * =	0.6400		F3 =	0.6309
CP * =	0.6450		F3 =	0.6549
CP * =	0.6500		F3 =	0.7508
CP * =	0.6550		F3 =	0.9265
CP * =	0.6600		F3 =	1.1836
CP * =	0.6650		F3 =	1.5172
CP * =	0.6700		F3 =	1.9146
CP * =	0.6750		F3 =	2.3563
CP * =	0.6800		F3 =	2.8164
CP * =	0.6850		F3 =	3.2639
CP * =	0.6900		F3 =	3.6644
CP * =	0.6950		F3 =	3.9826
CP * =	0.7000		F3 =	4.1839

$V/\sqrt{L} = .85$

CP * = 0.4800	F3 = 3.2635
CP * = 0.4850	F3 = 3.2389
CP * = 0.4900	F3 = 3.2026
CP * = 0.4950	F3 = 3.1447
CP * = 0.5000	F3 = 3.0573
CP * = 0.5050	F3 = 2.9361
CP * = 0.5100	F3 = 2.7805
CP * = 0.5150	F3 = 2.5940
CP * = 0.5200	F3 = 2.3839
CP * = 0.5250	F3 = 2.1608
CP * = 0.5300	F3 = 1.9375
CP * = 0.5350	F3 = 1.7277
CP * = 0.5400	F3 = 1.5448
CP * = 0.5450	F3 = 1.4094
CP * = 0.5500	F3 = 1.3031
CP * = 0.5550	F3 = 1.2576
CP * = 0.5600	F3 = 1.2640
CP * = 0.5650	F3 = 1.3177
CP * = 0.5700	F3 = 1.4097
CP * = 0.5750	F3 = 1.5273
CP * = 0.5800	F3 = 1.6554
CP * = 0.5850	F3 = 1.7776
CP * = 0.5900	F3 = 1.8786
CP * = 0.5950	F3 = 1.9449
CP * = 0.6000	F3 = 1.9672
CP * = 0.6050	F3 = 1.9412
CP * = 0.6100	F3 = 1.8686
CP * = 0.6150	F3 = 1.7572
CP * = 0.6200	F3 = 1.6210
CP * = 0.6250	F3 = 1.4791
CP * = 0.6300	F3 = 1.3541
CP * = 0.6350	F3 = 1.2706
CP * = 0.6400	F3 = 1.2526
CP * = 0.6450	F3 = 1.3214
CP * = 0.6500	F3 = 1.4930
CP * = 0.6550	F3 = 1.7760
CP * = 0.6600	F3 = 2.1701
CP * = 0.6650	F3 = 2.6650
CP * = 0.6700	F3 = 3.2335
CP * = 0.6750	F3 = 3.8627
CP * = 0.6800	F3 = 4.4946
CP * = 0.6850	F3 = 5.0885
CP * = 0.6900	F3 = 5.5931
CP * = 0.6950	F3 = 5.9563
CP * = 0.7000	F3 = 6.1280

$V/\sqrt{L} = .9$

CP * = 0.4800	F3 = 3.4679
CP * = 0.4850	F3 = 3.4058
CP * = 0.4900	F3 = 3.3349
CP * = 0.4950	F3 = 3.2474
CP * = 0.5000	F3 = 3.1375
CP * = 0.5050	F3 = 3.0026
CP * = 0.5100	F3 = 2.8431
CP * = 0.5150	F3 = 2.6629
CP * = 0.5200	F3 = 2.4694
CP * = 0.5250	F3 = 2.2724
CP * = 0.5300	F3 = 2.0835
CP * = 0.5350	F3 = 1.9150
CP * = 0.5400	F3 = 1.7787
CP * = 0.5450	F3 = 1.6848
CP * = 0.5500	F3 = 1.6404
CP * = 0.5550	F3 = 1.6492
CP * = 0.5600	F3 = 1.7107
CP * = 0.5650	F3 = 1.8200
CP * = 0.5700	F3 = 1.9687
CP * = 0.5750	F3 = 2.1446
CP * = 0.5800	F3 = 2.3338
CP * = 0.5850	F3 = 2.5213
CP * = 0.5900	F3 = 2.6929
CP * = 0.5950	F3 = 2.8366
CP * = 0.6000	F3 = 2.9438
CP * = 0.6050	F3 = 3.0107
CP * = 0.6100	F3 = 3.0386
CP * = 0.6150	F3 = 3.0349
CP * = 0.6200	F3 = 3.0117
CP * = 0.6250	F3 = 2.9861
CP * = 0.6300	F3 = 2.9781
CP * = 0.6350	F3 = 3.0092
CP * = 0.6400	F3 = 3.1002
CP * = 0.6450	F3 = 3.2691
CP * = 0.6500	F3 = 3.5290
CP * = 0.6550	F3 = 3.8864
CP * = 0.6600	F3 = 4.3391
CP * = 0.6650	F3 = 4.8759
CP * = 0.6700	F3 = 5.4759
CP * = 0.6750	F3 = 6.1092
CP * = 0.6800	F3 = 6.7380
CP * = 0.6850	F3 = 7.3181
CP * = 0.6900	F3 = 7.8021
CP * = 0.6950	F3 = 8.1414
CP * = 0.7000	F3 = 8.2900

$V/\sqrt{L} = .95$

C *	=	0.4800	F3	=	2.7801
C *	=	0.4850	F3	=	2.8750
C *	=	0.4900	F3	=	2.9551
C *	=	0.4950	F3	=	3.0071
C *	=	0.5000	F3	=	3.0206
C *	=	0.5050	F3	=	2.9896
C *	=	0.5100	F3	=	2.9124
C *	=	0.5150	F3	=	2.7930
C *	=	0.5200	F3	=	2.6399
C *	=	0.5250	F3	=	2.4659
C *	=	0.5300	F3	=	2.2868
C *	=	0.5350	F3	=	2.1199
C *	=	0.5400	F3	=	1.9828
C *	=	0.5450	F3	=	1.8913
C *	=	0.5500	F3	=	1.8581
C *	=	0.5550	F3	=	1.8915
C *	=	0.5600	F3	=	1.9946
C *	=	0.5650	F3	=	2.1653
C *	=	0.5700	F3	=	2.3958
C *	=	0.5750	F3	=	2.6739
C *	=	0.5800	F3	=	2.9840
C *	=	0.5850	F3	=	3.3087
C *	=	0.5900	F3	=	3.6305
C *	=	0.5950	F3	=	3.9338
C *	=	0.6000	F3	=	4.2064
C *	=	0.6050	F3	=	4.4413
C *	=	0.6100	F3	=	4.6375
C *	=	0.6150	F3	=	4.8005
C *	=	0.6200	F3	=	4.9420
C *	=	0.6250	F3	=	5.0792
C *	=	0.6300	F3	=	5.2336
C *	=	0.6350	F3	=	5.4282
C *	=	0.6400	F3	=	5.6862
C *	=	0.6450	F3	=	6.0276
C *	=	0.6500	F3	=	6.4672
C *	=	0.6550	F3	=	7.0121
C *	=	0.6600	F3	=	7.6599
C *	=	0.6650	F3	=	8.3975
C *	=	0.6700	F3	=	9.2007
C *	=	0.6750	F3	=	10.0348
C *	=	0.6800	F3	=	10.8555
C *	=	0.6850	F3	=	11.6114
C *	=	0.6900	F3	=	12.2469
C *	=	0.6950	F3	=	12.7053
C *	=	0.7000	F3	=	12.9325

$V/\sqrt{L} = 1.0$

CP *	=	0.4800	F3	=	2.8472
CP *	=	0.4850	F3	=	3.0410
CP *	=	0.4900	F3	=	3.2187
CP *	=	0.4950	F3	=	3.3655
CP *	=	0.5000	F3	=	3.4692
CP *	=	0.5050	F3	=	3.5211
CP *	=	0.5100	F3	=	3.5172
CP *	=	0.5150	F3	=	3.4579
CP *	=	0.5200	F3	=	3.3484
CP *	=	0.5250	F3	=	3.1987
CP *	=	0.5300	F3	=	3.0220
CP *	=	0.5350	F3	=	2.8347
CP *	=	0.5400	F3	=	2.6543
CP *	=	0.5450	F3	=	2.4990
CP *	=	0.5500	F3	=	2.3857
CP *	=	0.5550	F3	=	2.3291
CP *	=	0.5600	F3	=	2.3406
CP *	=	0.5650	F3	=	2.4280
CP *	=	0.5700	F3	=	2.5944
CP *	=	0.5750	F3	=	2.8387
CP *	=	0.5800	F3	=	3.1557
CP *	=	0.5850	F3	=	3.5371
CP *	=	0.5900	F3	=	3.9716
CP *	=	0.5950	F3	=	4.4470
CP *	=	0.6000	F3	=	4.9503
CP *	=	0.6050	F3	=	5.4697
CP *	=	0.6100	F3	=	5.9951
CP *	=	0.6150	F3	=	6.5190
CP *	=	0.6200	F3	=	7.0372
CP *	=	0.6250	F3	=	7.5486
CP *	=	0.6300	F3	=	8.0556
CP *	=	0.6350	F3	=	8.5632
CP *	=	0.6400	F3	=	9.0784
CP *	=	0.6450	F3	=	9.6095
CP *	=	0.6500	F3	=	10.1647
CP *	=	0.6550	F3	=	10.7511
CP *	=	0.6600	F3	=	11.3741
CP *	=	0.6650	F3	=	12.0357
CP *	=	0.6700	F3	=	12.7347
CP *	=	0.6750	F3	=	13.4660
CP *	=	0.6800	F3	=	14.2210
CP *	=	0.6850	F3	=	14.9874
CP *	=	0.6900	F3	=	15.7506
CP *	=	0.6950	F3	=	16.4941
CP *	=	0.7000	F3	=	17.2013

$V/\sqrt{L} = 1.05$		$V/\sqrt{L} = 1.1$	
CP * = 0.4800	F3 = 4.5072	CP * = 0.4800	F3 = 8.5303
CP * = 0.4850	F3 = 4.7743	CP * = 0.4850	F3 = 8.6040
CP * = 0.4900	F3 = 5.0176	CP * = 0.4900	F3 = 8.6533
CP * = 0.4950	F3 = 5.2150	CP * = 0.4950	F3 = 8.6558
CP * = 0.5000	F3 = 5.3483	CP * = 0.5000	F3 = 8.5933
CP * = 0.5050	F3 = 5.4045	CP * = 0.5050	F3 = 8.4537
CP * = 0.5100	F3 = 5.3766	CP * = 0.5100	F3 = 8.2316
CP * = 0.5150	F3 = 5.2646	CP * = 0.5150	F3 = 7.9293
CP * = 0.5200	F3 = 5.0754	CP * = 0.5200	F3 = 7.5563
CP * = 0.5250	F3 = 4.8221	CP * = 0.5250	F3 = 7.1292
CP * = 0.5300	F3 = 4.5234	CP * = 0.5300	F3 = 6.6696
CP * = 0.5350	F3 = 4.2019	CP * = 0.5350	F3 = 6.2030
CP * = 0.5400	F3 = 3.8825	CP * = 0.5400	F3 = 5.7565
CP * = 0.5450	F3 = 3.5908	CP * = 0.5450	F3 = 5.3567
CP * = 0.5500	F3 = 3.3507	CP * = 0.5500	F3 = 5.0274
CP * = 0.5550	F3 = 3.1836	CP * = 0.5550	F3 = 4.7883
CP * = 0.5600	F3 = 3.1060	CP * = 0.5600	F3 = 4.6529
CP * = 0.5650	F3 = 3.1292	CP * = 0.5650	F3 = 4.6283
CP * = 0.5700	F3 = 3.2584	CP * = 0.5700	F3 = 4.7143
CP * = 0.5750	F3 = 3.4928	CP * = 0.5750	F3 = 4.9041
CP * = 0.5800	F3 = 3.8259	CP * = 0.5800	F3 = 5.1854
CP * = 0.5850	F3 = 4.2463	CP * = 0.5850	F3 = 5.5415
CP * = 0.5900	F3 = 4.7392	CP * = 0.5900	F3 = 5.9534
CP * = 0.5950	F3 = 5.2877	CP * = 0.5950	F3 = 6.4016
CP * = 0.6000	F3 = 5.8743	CP * = 0.6000	F3 = 6.8665
CP * = 0.6050	F3 = 6.4828	CP * = 0.6050	F3 = 7.3398
CP * = 0.6100	F3 = 7.0992	CP * = 0.6100	F3 = 7.8062
CP * = 0.6150	F3 = 7.7134	CP * = 0.6150	F3 = 8.2645
CP * = 0.6200	F3 = 8.3193	CP * = 0.6200	F3 = 8.7177
CP * = 0.6250	F3 = 8.9156	CP * = 0.6250	F3 = 9.1748
CP * = 0.6300	F3 = 9.5055	CP * = 0.6300	F3 = 9.6495
CP * = 0.6350	F3 = 10.0956	CP * = 0.6350	F3 = 10.1594
CP * = 0.6400	F3 = 10.6958	CP * = 0.6400	F3 = 10.7230
CP * = 0.6450	F3 = 11.3170	CP * = 0.6450	F3 = 11.3579
CP * = 0.6500	F3 = 11.9704	CP * = 0.6500	F3 = 12.0783
CP * = 0.6550	F3 = 12.6654	CP * = 0.6550	F3 = 12.8928
CP * = 0.6600	F3 = 13.4088	CP * = 0.6600	F3 = 13.8021
CP * = 0.6650	F3 = 14.2029	CP * = 0.6650	F3 = 14.7979
CP * = 0.6700	F3 = 15.0454	CP * = 0.6700	F3 = 15.8621
CP * = 0.6750	F3 = 15.9286	CP * = 0.6750	F3 = 16.9668
CP * = 0.6800	F3 = 16.8395	CP * = 0.6800	F3 = 18.0753
CP * = 0.6850	F3 = 17.7606	CP * = 0.6850	F3 = 19.1438
CP * = 0.6900	F3 = 18.6708	CP * = 0.6900	F3 = 20.1239
CP * = 0.6950	F3 = 19.5468	CP * = 0.6950	F3 = 20.9653
CP * = 0.7000	F3 = 20.3647	CP * = 0.7000	F3 = 21.6194

$V/\sqrt{L} = 1.15$		$V/\sqrt{L} = 1.2$	
CP * = 0.4800	F3 = 13.3153	CP * = 0.4800	F3 = 20.2021
CP * = 0.4850	F3 = 13.6364	CP * = 0.4850	F3 = 20.3639
CP * = 0.4900	F3 = 13.9036	CP * = 0.4900	F3 = 20.4780
CP * = 0.4950	F3 = 14.0911	CP * = 0.4950	F3 = 20.5006
CP * = 0.5000	F3 = 14.1444	CP * = 0.5000	F3 = 20.3951
CP * = 0.5050	F3 = 14.0436	CP * = 0.5050	F3 = 20.1353
CP * = 0.5100	F3 = 13.7752	CP * = 0.5100	F3 = 19.7070
CP * = 0.5150	F3 = 13.3395	CP * = 0.5150	F3 = 19.1094
CP * = 0.5200	F3 = 12.7501	CP * = 0.5200	F3 = 18.3550
CP * = 0.5250	F3 = 12.0329	CP * = 0.5250	F3 = 17.4686
CP * = 0.5300	F3 = 11.2241	CP * = 0.5300	F3 = 16.4848
CP * = 0.5350	F3 = 10.3668	CP * = 0.5350	F3 = 15.4459
CP * = 0.5400	F3 = 9.5078	CP * = 0.5400	F3 = 14.3979
CP * = 0.5450	F3 = 8.6936	CP * = 0.5450	F3 = 13.3869
CP * = 0.5500	F3 = 7.9663	CP * = 0.5500	F3 = 12.4562
CP * = 0.5550	F3 = 7.3631	CP * = 0.5550	F3 = 11.6420
CP * = 0.5600	F3 = 6.9081	CP * = 0.5600	F3 = 10.9720
CP * = 0.5650	F3 = 6.6164	CP * = 0.5650	F3 = 10.4629
CP * = 0.5700	F3 = 6.4902	CP * = 0.5700	F3 = 10.1199
CP * = 0.5750	F3 = 6.5207	CP * = 0.5750	F3 = 9.9370
CP * = 0.5800	F3 = 6.6886	CP * = 0.5800	F3 = 9.8985
CP * = 0.5850	F3 = 6.9673	CP * = 0.5850	F3 = 9.9808
CP * = 0.5900	F3 = 7.3255	CP * = 0.5900	F3 = 10.1554
CP * = 0.5950	F3 = 7.7309	CP * = 0.5950	F3 = 10.3919
CP * = 0.6000	F3 = 8.1534	CP * = 0.6000	F3 = 10.6615
CP * = 0.6050	F3 = 8.5684	CP * = 0.6050	F3 = 10.9397
CP * = 0.6100	F3 = 8.9596	CP * = 0.6100	F3 = 11.2091
CP * = 0.6150	F3 = 9.3201	CP * = 0.6150	F3 = 11.4610
CP * = 0.6200	F3 = 9.6538	CP * = 0.6200	F3 = 11.6960
CP * = 0.6250	F3 = 9.9745	CP * = 0.6250	F3 = 11.9240
CP * = 0.6300	F3 = 10.3047	CP * = 0.6300	F3 = 12.1631
CP * = 0.6350	F3 = 10.6724	CP * = 0.6350	F3 = 12.4367
CP * = 0.6400	F3 = 11.1086	CP * = 0.6400	F3 = 12.7714
CP * = 0.6450	F3 = 11.6428	CP * = 0.6450	F3 = 13.1926
CP * = 0.6500	F3 = 12.2391	CP * = 0.6500	F3 = 13.7217
CP * = 0.6550	F3 = 13.0923	CP * = 0.6550	F3 = 14.3719
CP * = 0.6600	F3 = 14.0248	CP * = 0.6600	F3 = 15.1457
CP * = 0.6650	F3 = 15.0840	CP * = 0.6650	F3 = 16.0322
CP * = 0.6700	F3 = 16.2410	CP * = 0.6700	F3 = 17.0061
CP * = 0.6750	F3 = 17.4510	CP * = 0.6750	F3 = 18.0276
CP * = 0.6800	F3 = 18.6543	CP * = 0.6800	F3 = 19.0437
CP * = 0.6850	F3 = 19.7792	CP * = 0.6850	F3 = 19.9906
CP * = 0.6900	F3 = 20.7464	CP * = 0.6900	F3 = 20.7972
CP * = 0.6950	F3 = 21.4734	CP * = 0.6950	F3 = 21.3898
CP * = 0.7000	F3 = 21.8806	CP * = 0.7000	F3 = 21.6966

APPENDIX C

Samples of Wave and Form Drag Prediction for the Taylor Standard Series Ships

LWL = 190.00 B = 13.53 T = 6.01 DISPL = 6843.2 CP = 0.48463 CM = 0.91407

CB = 0.44298 CV = 0.00100 S = 2943. CS = 2.5811

S/LWL**2 = 0.08152896 FO + F1*DISPL/(LWL**3) =0.00001635

SLR	F	DISPL *	CP *	CM *	CB *	CV *	CCR	LCB *	F2
0.50	0.149	4007.	0.5117	0.5065	0.2594	C.000584	0.2200	0.0020	0.000000
0.55	0.164	4356.	0.5074	0.5557	0.2820	0.000635	0.2200	0.0010	0.000000
0.60	0.179	4653.	0.5039	0.5977	0.3012	C.000678	0.2200	0.0003	0.000000
0.65	0.193	4906.	0.5012	0.6336	0.3176	C.000715	0.2200	-0.0003	0.000000
0.70	0.208	5121.	0.4990	0.6643	0.3315	C.000747	0.2200	-0.0008	0.000000
0.75	0.223	5306.	0.4972	0.6907	0.3434	C.000774	0.2200	-0.0012	0.000000
0.80	0.238	5464.	0.4957	0.7134	0.3537	C.000797	0.2200	-0.0015	0.000000
0.85	0.253	5600.	0.4945	0.7331	0.3625	C.000816	0.2200	-0.0018	0.000000
0.90	0.268	5718.	0.4935	0.7501	C.3701	C.000834	0.2200	-0.0020	0.000000
0.95	0.283	5821.	0.4926	0.7645	0.3768	0.000849	0.2200	-0.0022	0.000000
1.C0	0.298	5910.	0.4918	0.7775	0.3826	C.000862	0.3000	-0.0023	8.784081
1.05	0.313	5989.	0.4911	0.7894	0.3877	0.000873	0.4200	-0.0025	21.385750
1.10	0.327	6059.	0.4906	0.7995	0.3922	C.000883	0.6100	-0.0026	40.750000
1.15	0.342	6120.	0.4901	0.8084	0.3962	C.000892	0.8700	-0.0027	66.555540
1.20	0.357	6175.	0.4896	0.8164	0.3997	0.000900	1.1500	-0.0028	93.542050

PREDICTED FORM DRAG COEFFICIENT = .20
FORM DRAG COEFFICIENT FROM MODEL TEST = .22

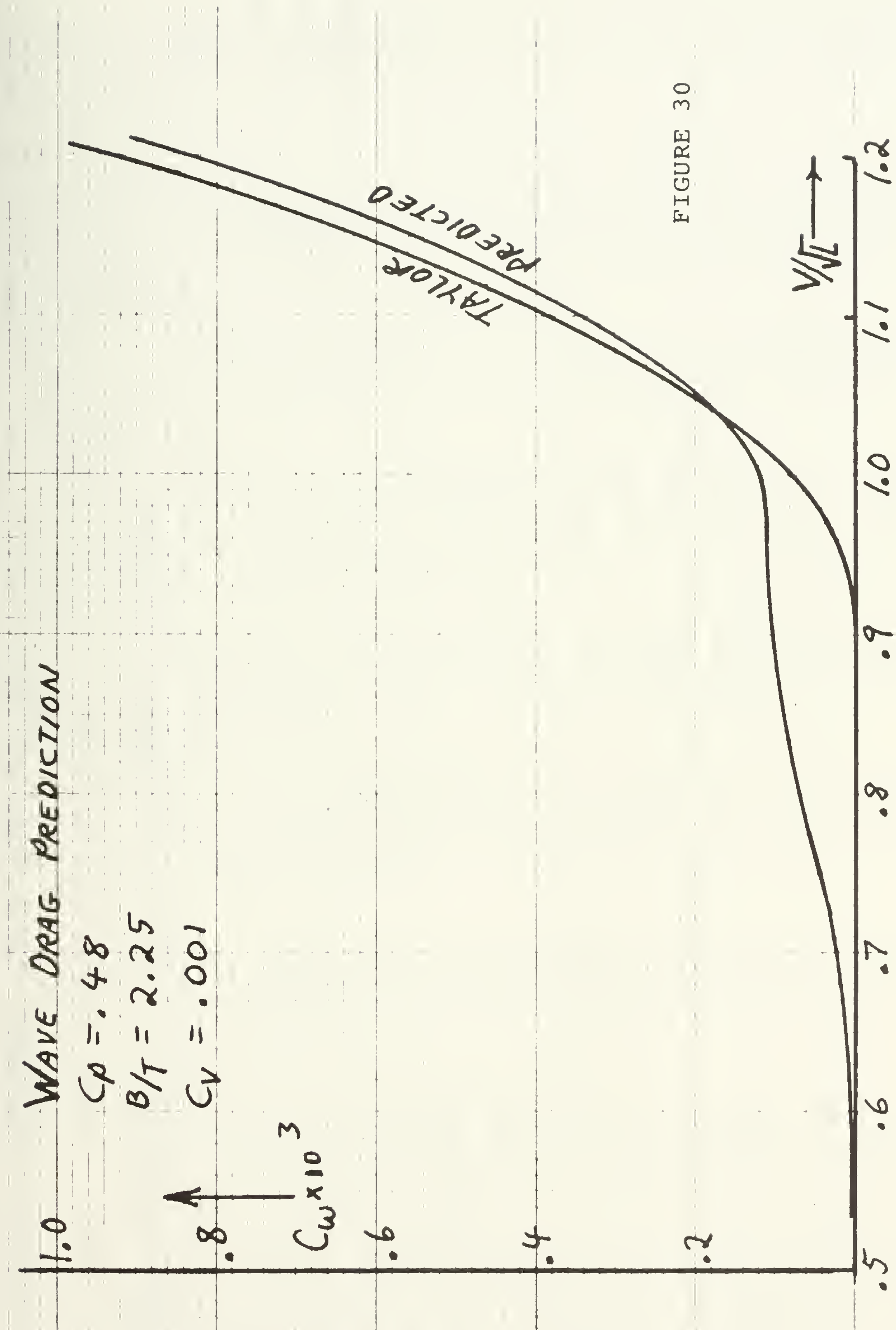

WAVE DRAG PREDICTION
$C_p = .48$
$B/T = 2.25$
$C_v = .001$
$C_w \times 10^3$
1.0
.8
.6
.4
.2
.5
.6
.7
.8
.9
1.0
1.1
1.2
TAYLOR
PREDICTED
$V/\sqrt{L}$

FIGURE 30

LWL = 190.00 B = 27.05 T = 12.02 DISPL = 27373.2 CP = 0.48463 CM = 0.91407

CB = 0.44298 CV = 0.00399 S = 5913. CS = 2.5927

S/LWL**2 = 0.16378770 F0 + F1*DISPL/(LWL**3) =0.00005825

SLR	F	DISPL *	CP *	CM *	CB *	CV *	CCR	LCB *	F2
0.50	0.149	10597.	0.5328	0.3218	0.1715	0.001545	0.3600	0.0068	0.000000
0.55	0.164	12087.	0.5263	0.3717	0.1956	0.001762	0.3600	0.0053	0.000000
0.60	0.179	13471.	0.5207	0.4186	0.2180	0.001964	0.3600	0.0040	0.000000
0.65	0.193	14734.	0.5161	0.4620	0.2384	0.002148	0.3700	0.0030	0.354955
0.70	0.208	15875.	0.5122	0.5016	0.2569	0.002315	0.4000	0.0021	1.222986
0.75	0.223	16900.	0.5089	0.5374	0.2735	0.002464	0.4800	0.0014	3.237514
0.80	0.238	17816.	0.5062	0.5696	0.2883	0.002598	0.6100	0.0008	6.068859
0.85	0.253	18634.	0.5039	0.5985	0.3016	0.002717	0.7300	0.0003	8.210750
0.90	0.268	19364.	0.5019	0.6244	0.3134	0.002823	0.7300	-0.0001	7.603600
0.95	0.283	20015.	0.5002	0.6475	0.3239	0.002918	0.7600	-0.0005	7.693825
1.00	0.298	20597.	0.4987	0.6683	0.3333	0.003003	0.8600	-0.0008	9.081390
1.05	0.313	21118.	0.4975	0.6870	0.3418	0.003079	1.2800	-0.0011	15.895250
1.10	0.327	21586.	0.4964	0.7038	0.3493	0.003147	2.0200	-0.0014	27.451870
1.15	0.342	22006.	0.4954	0.7189	0.3561	0.003208	3.2500	-0.0016	45.984930
1.20	0.357	22385.	0.4945	0.7325	0.3623	0.003264	4.7400	-0.0017	67.355450

PREDICTED FORM DRAG COEFFICIENT = .356
FORM DRAG COEFFICIENT FROM MODEL TEST = .360

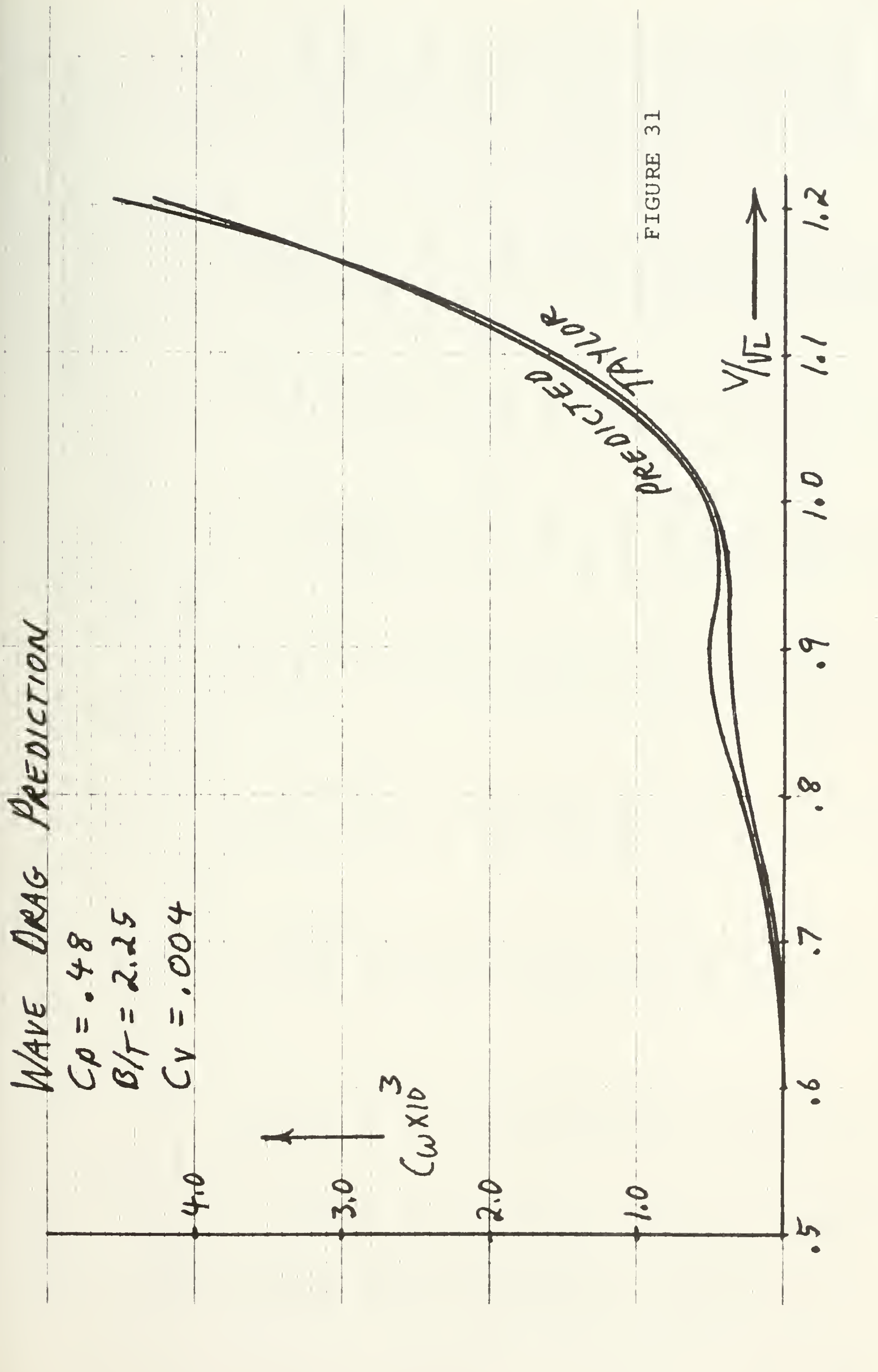

WAVE DRAG PREDICTION
$C_p = .48$
$B/T = 2.25$
$C_V = .004$
$C_W \times 10^3$
4.0
3.0
2.0
1.0
.5
.6
.7
.8
.9
1.0
1.1
1.2
PREDICTED
TAYLOR
$V/\sqrt{L}$

FIGURE 31

LWL = 190.00 B = 34.92 T = 9.31 DISPL = 27373.1 CP = 0.48463 CM = 0.91407

CB = 0.44298 CV = 0.00399 S = 5818. CS = 2.5511

S/LWL**2 = 0.16116240 FO + F1*DISPL/(LWL**3) =0.000C7982

SLR	F	DISPL *	CP *	CM *	CB *	CV *	CCR	LCB *	F2
0.50	0.149	12602.	0.5241	0.3891	0.2039	C.001837	0.4800	0.0048	0.000000
0.55	0.164	14115.	0.5183	0.4407	0.2284	C.002058	0.4900	0.0035	0.380534
0.60	0.179	15472.	0.5135	0.4876	0.2504	C.002256	0.5000	0.0024	0.633460
0.65	0.193	16675.	0.5096	0.5295	0.2699	C.002431	0.5000	0.0015	0.545355
0.70	0.208	17735.	0.5064	0.5667	0.2870	C.002586	0.5600	0.0008	1.928371
0.75	0.223	18668.	0.5038	0.5997	0.3021	C.002722	0.6800	0.0003	4.351535
0.80	0.238	19486.	0.5016	0.6287	0.3153	0.002841	0.8300	-0.0002	6.988720
0.85	0.253	20206.	0.4997	0.6544	0.3270	C.002946	0.9900	-0.0006	9.470976
0.90	0.268	20840.	0.4981	0.677C	0.3373	C.003038	1.0900	-0.0010	10.649420
0.95	0.283	21399.	0.4968	0.6971	0.3463	C.C03120	1.1500	-0.0013	11.093230
1.C0	0.298	21895.	0.4956	0.7149	0.3543	0.003192	1.29C0	-0.0015	12.811410
1.05	0.313	22334.	0.4946	0.7307	0.3614	C.003256	1.5900	-0.0017	16.872020
1.10	0.327	22726.	0.4938	0.7448	0.3678	C.C03313	2.1900	-0.0019	25.104260
1.15	0.342	23075.	0.4930	0.7575	0.3734	C.003364	3.1900	-0.0021	38.588540
1.20	0.357	23389.	0.4923	0.7688	0.3785	C.003410	4.6300	-0.0022	57.520850

PREDICTED FORM DRAG COEFFICIENT = .495
FORM DRAG COEFFICIENT FROM MODEL TEST = .480

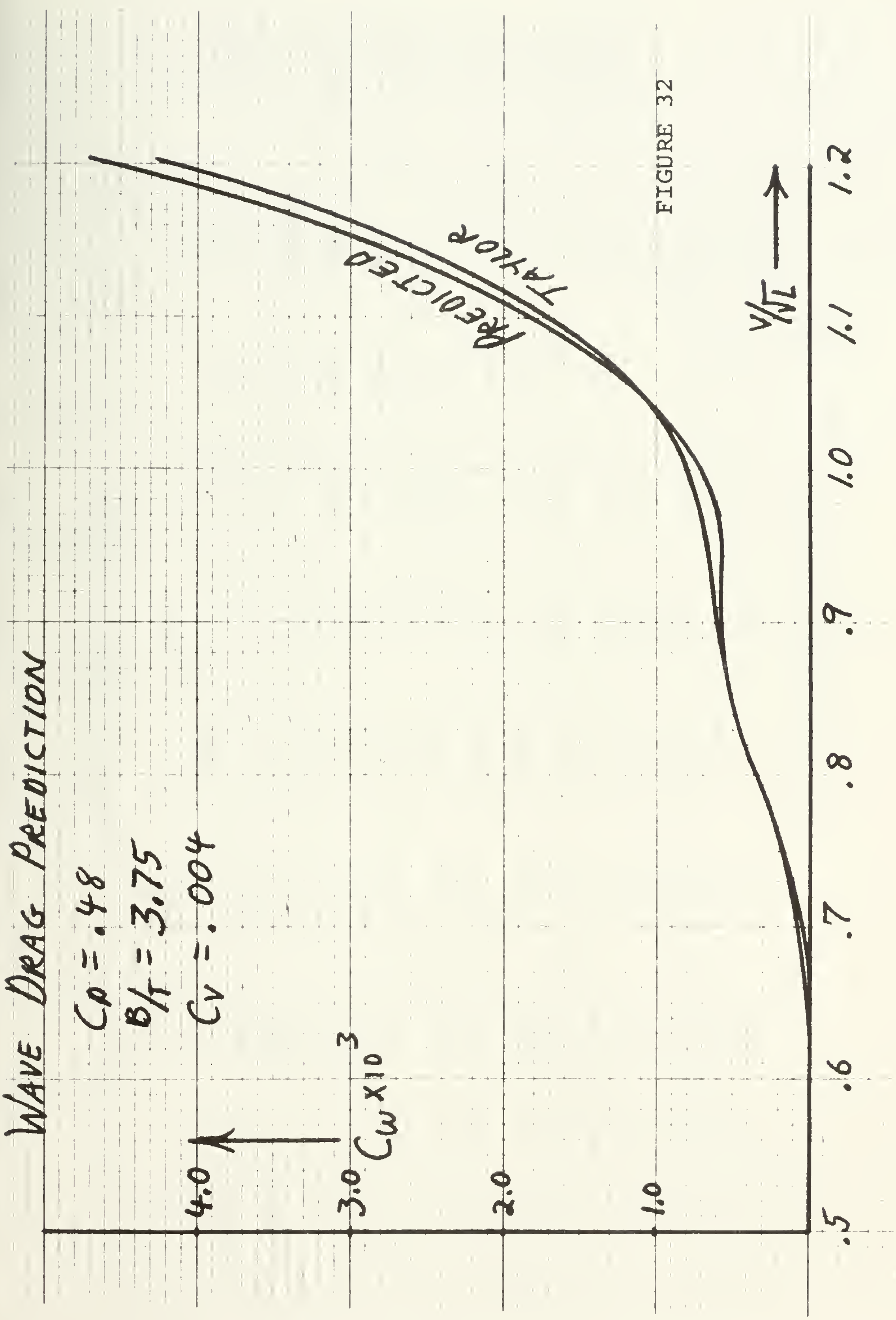

WAVE DRAG PREDICTION
$C_P = .48$
$B/T = 3.75$
$C_V = .004$
$C_W \times 10^3$
4.0
3.0
2.0
1.0
.5
.6
.7
.8
.9
1.0
1.1
1.2
$V/\sqrt{L}$
PREDICTED
TAYLOR

FIGURE 32

LWL = 190.00 B = 46.20 T = 12.32 DISPL = 479C3.1 CP = 0.48463 CM = 0.91407

CB = 0.44298 CV = 0.00698 S = 7735. CS = 2.5639

S/LWL**2 = 0.21426E30 FC + F1*DISPL/(LWL**3) =0.00013825

SLR	F	DISPL *	CP *	CM *	CB *	CV *	CCR	LCB *	F2
0.50	0.149	18218.	0.5337	0.3157	0.1685	0.002656	0.7000	0.0070	0.000000
0.55	0.164	20815.	0.5271	0.3652	C.1925	0.C03035	0.7000	0.0055	0.000000
0.60	0.179	23234.	0.5215	0.412C	0.2149	C.003387	0.7200	0.0042	0.373472
0.65	0.193	2545C.	0.5167	0.4554	0.2353	C.003710	0.7600	0.0031	0.933809
0.70	0.208	27457.	0.5128	0.4951	0.2539	C.C04003	0.8400	0.0023	1.871922
0.75	0.223	29263.	0.5095	0.5311	0.2706	C.004266	1.0400	0.0015	4.002253
0.80	0.238	30882.	0.5067	0.5636	0.2856	C.004502	1.3500	0.0009	6.870553
0.85	0.253	32328.	0.5043	0.5928	0.2990	C.C04713	1.7000	0.0004	9.645301
0.90	0.268	3362C.	0.5023	0.6189	0.3109	C.004902	1.8600	-0.0001	10.344920
0.95	0.283	34775.	0.5006	0.6424	0.3216	C.005070	2.0400	-0.0004	11.169590
1.00	0.298	35809.	0.4991	0.6635	0.3311	C.C05221	2.3400	-0.0008	12.892730
1.C5	0.313	36734.	0.4978	0.6824	C.3397	C.005356		-0.0010	
1.10	0.327	37566.	0.4966	0.6995	0.3474	C.C05477	4.2	-0.0013	
1.15	0.342	38313.	0.4957	0.7148	0.3543	0.005586		-0.0015	
1.20	0.357	38987.	0.4948	0.7287	0.3605	0.005684	9.0	-0.0017	

PREDICTED FORM DRAG COEFFICIENT = .645
FORM DRAG COEFFICIENT FROM MODEL TEST = .70

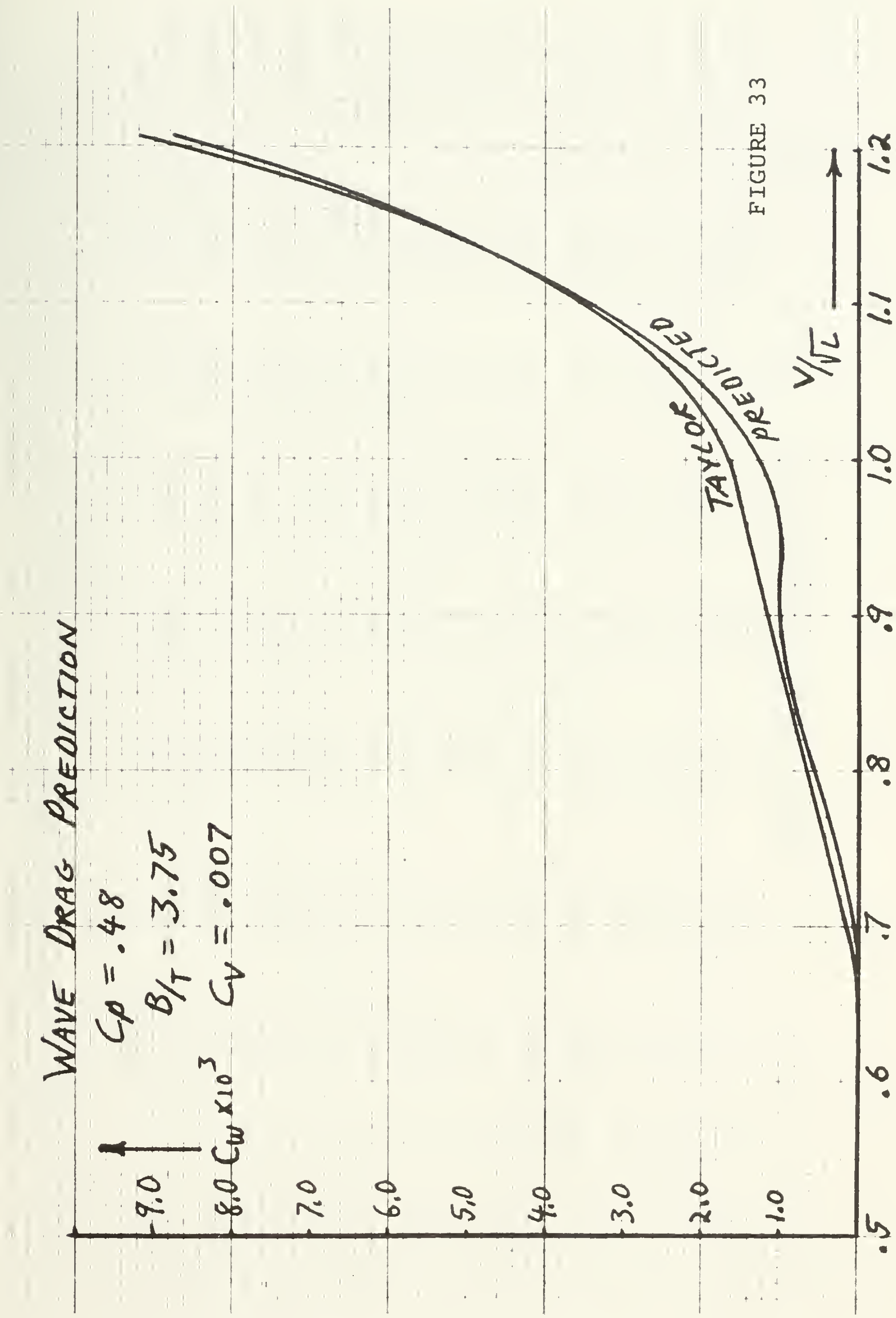

WAVE DRAG PREDICTION
$C_P = .48$
$B/T = 3.75$
$C_V = .007$
$C_W \times 10^3$
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
.5
.6
.7
.8
.9
1.0
1.1
1.2
$V/\sqrt{L}$
TAYLOR
PREDICTED

FIGURE 33

LWL = 190.00 B = 12.75 T = 5.67 DISPL = 6810.2 CP = 0.54271 CM = 0.91407

CB = 0.49607 CV = 0.00099 S = 2914. CS = 2.5619

S/LWL**2 = 0.08072525 PO + P1*DISPL/(LWL**3) =0.00001750

SLR	P	DISPL *	CP *	CM *	CB *	CV *	CCR	LCB *	P2
0.50	0.149	4075.	0.5684	0.5223	0.2969	0.000594	0.2300	0.0012	0.000000
0.55	0.164	4417.	0.5643	0.5703	0.3218	0.000644	0.2300	0.0004	0.000000
0.60	0.179	4707.	0.5610	0.6112	0.3429	0.000686	0.2300	-0.0003	0.000000
0.65	0.193	4953.	0.5584	0.6461	0.3608	0.000722	0.2300	-0.0008	0.000000
0.70	0.208	5162.	0.5563	0.6759	0.3760	0.000753	0.2300	-0.0012	0.000000
0.75	0.223	5340.	0.5546	0.7013	0.3890	0.000779	0.2300	-0.0015	0.000000
0.80	0.238	5493.	0.5532	0.7232	0.4001	0.000801	0.2300	-0.0018	0.000000
0.85	0.253	5624.	0.5521	0.7420	0.4096	0.000820	0.2300	-0.0020	0.000000
0.90	0.268	5737.	0.5511	0.7583	0.4179	0.000836	0.2300	-0.0022	0.000000
0.95	0.283	5835.	0.5502	0.7725	0.4251	0.000851	0.2400	-0.0023	1.145255
1.00	0.298	5922.	0.5495	0.7850	0.4313	0.000863	0.2600	-0.0025	3.249248
1.05	0.313	5997.	0.5489	0.7959	0.4368	0.000874	0.2900	-0.0026	6.335935
1.10	0.327	6064.	0.5483	0.8055	0.4417	0.000884	0.3800	-0.0027	15.494140
1.15	0.342	6122.	0.5479	0.8140	0.4460	0.000893	0.5300	-0.0028	30.394850
1.20	0.357	6175.	0.5474	0.8216	0.4498	0.000900	0.7500	-0.0029	51.794540

PREDICTED FORM DRAG COEFFICIENT = .217
FORM DRAG COEFFICIENT FROM MODEL TEST = .230

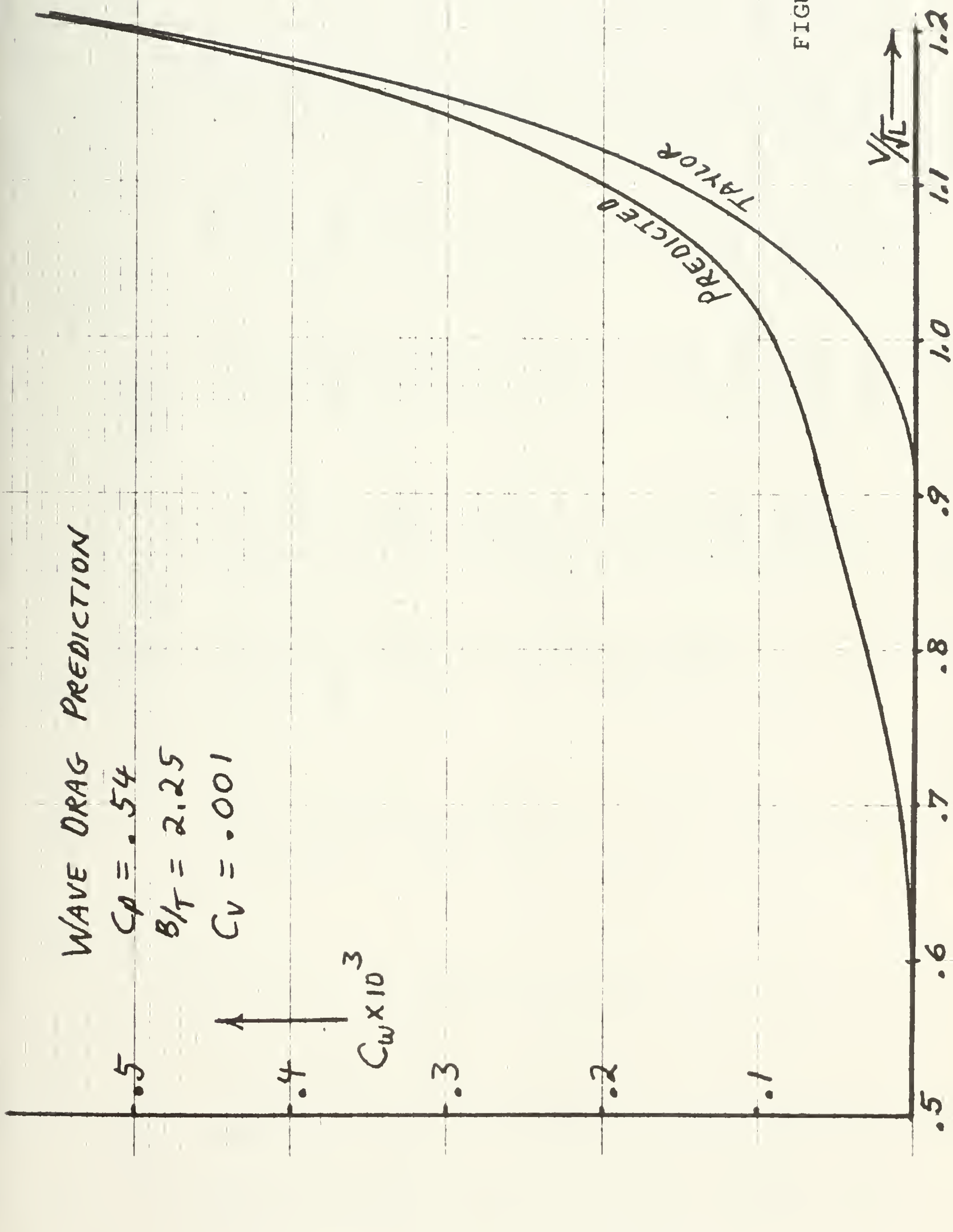

WAVE DRAG PREDICTION
$C_p = .54$
$B/T = 2.25$
$C_V = .001$
$C_W \times 10^3$
.5
.4
.3
.2
.1
PREDICTED
TAYLOR
.5
.6
.7
.8
.9
1.0
1.1
1.2
$V/\sqrt{L}$

FIGURE 34

LWL = 190.00   B = 22.09   T = 9.82   DISPL = 20435.7   CP = 0.54271   CM = 0.91407

CB = 0.49607   CV = 0.00298   S = 5062.   CS = 2.5687

S/LWL**2 = 0.14021120   PO + P1*DISPL/(LWL**3) =0.00004531

SLR	F	DISPL *	CP *	CM *	CB *	CV *	CCR	LCB *	F2
0.50	0.149	9018.	0.5838	0.3749	0.2189	0.001315	0.3300	0.0043	0.000000
0.55	0.164	10152.	0.5779	0.4264	0.2464	0.001480	0.3400	0.0031	0.640056
0.60	0.179	11176.	0.5730	0.4735	0.2713	0.001629	0.3400	0.0021	0.528071
0.65	0.193	12091.	0.5690	0.5159	0.2935	0.001763	0.3400	0.0013	0.451189
0.70	0.208	12902.	0.5656	0.5537	0.3132	0.001881	0.3400	0.0006	0.396258
0.75	0.223	13618.	0.5629	0.5873	0.3306	0.001985	0.3600	0.0001	1.067063
0.80	0.238	14250.	0.5606	0.6171	0.3459	0.002078	0.3900	-0.0003	1.949175
0.85	0.253	14807.	0.5586	0.6434	0.3594	0.002159	0.4300	-0.0007	3.008821
0.90	0.268	15298.	0.5570	0.6668	0.3714	0.002230	0.5200	-0.0010	5.355082
0.95	0.283	15734.	0.5556	0.6875	0.3819	0.002294	0.6000	-0.0013	7.194690
1.00	0.298	16120.	0.5543	0.7059	0.3913	0.002350	0.6800	-0.0015	8.885139
1.05	0.313	16463.	0.5533	0.7223	0.3996	0.002400	0.8200	-0.0017	11.925810
1.10	0.327	16769.	0.5524	0.7369	0.4071	0.002445	1.0800	-0.0019	17.593390
1.15	0.342	17043.	0.5516	0.7501	0.4137	0.002485	1.5000	-0.0021	26.570810
1.20	0.357	17288.	0.5509	0.7619	0.4197	0.002521	2.2500	-0.0022	42.373220

PREDICTED FORM DRAG COEFFICIENT = .323
FORM DRAG COEFFICIENT FROM MODEL TEST = .330

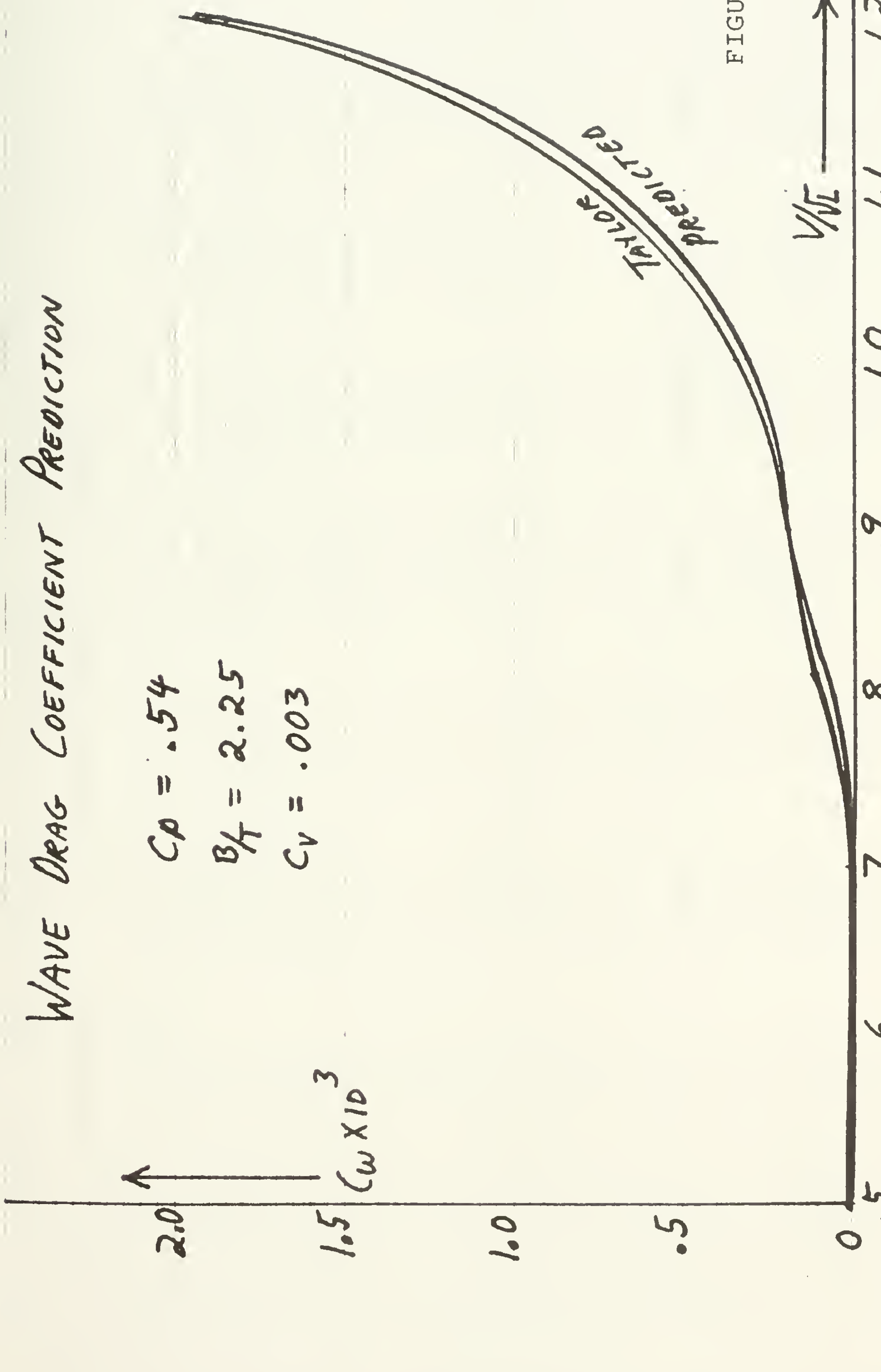

WAVE DRAG COEFFICIENT PREDICTION
$C_P = .54$
$B/T = 2.25$
$C_V = .003$
$C_W \times 10^3$
2.0
1.5
1.0
.5
0
.5
.6
.7
.8
.9
1.0
1.1
1.2
$V/\sqrt{L}$
TAYLOR
PREDICTED

FIGURE 35

LWL = 190.00 B = 36.81 T = 9.82 DISPL = 34059.5 CP = 0.54271 CM = 0.91407

CB = 0.49607 CV = 0.00497 S = 6538. CS = 2.5700

S/LWL**2 = 0.18110480 F0 + F1*DISPL/(LWL**3) =0.00011080

SLR	F	DISPL *	CP *	CM *	CB *	CV *	CCR	LCB *	F2
0.50	0.149	15030.	0.5838	0.3749	0.2189	0.002191	0.6200	0.0043	0.000000
0.55	0.164	16920.	0.5779	0.4264	0.2464	0.002467	0.6200	0.0031	0.000000
0.60	0.179	18627.	0.5730	0.4735	0.2713	0.002716	0.6300	0.0021	0.245557
0.65	0.193	20152.	0.5690	0.5159	0.2935	0.002938	0.6600	0.0013	0.839217
0.70	0.208	21503.	0.5656	0.5537	0.3132	0.003135	0.7000	0.0006	1.474086
0.75	0.223	22697.	0.5629	0.5873	0.3306	0.003309	0.7700	0.0001	2.480895
0.80	0.238	23749.	0.5606	0.6171	0.3459	0.003463	0.8700	-0.0003	3.776484
0.85	0.253	24678.	0.5586	0.6434	0.3594	0.003598	0.9500	-0.0007	4.616993
0.90	0.268	25497.	0.5570	0.6668	0.3714	0.003717	1.0500	-0.0010	5.635467
0.95	0.283	26223.	0.5556	0.6875	0.3819	0.003823	1.1900	-0.0013	7.062708
1.00	0.298	26866.	0.5543	0.7059	0.3913	0.003917	1.3600	-0.0015	8.735271
1.05	0.313	27438.	0.5533	0.7223	0.3996	0.004000	1.6200	-0.0017	11.317290
1.10	0.327	27948.	0.5524	0.7369	0.4071	0.004075	2.1000	-0.0019	16.143550
1.15	0.342	28405.	0.5516	0.7501	0.4137	0.004141	2.9000	-0.0021	24.077100
1.20	0.357	28814.	0.5509	0.7619	0.4197	0.004201	4.0700	-0.0022	35.404490

PREDICTED FORM DRAG COEFFICIENT = .612
FORM DRAG COEFFICIENT FROM MODEL TEST = .620

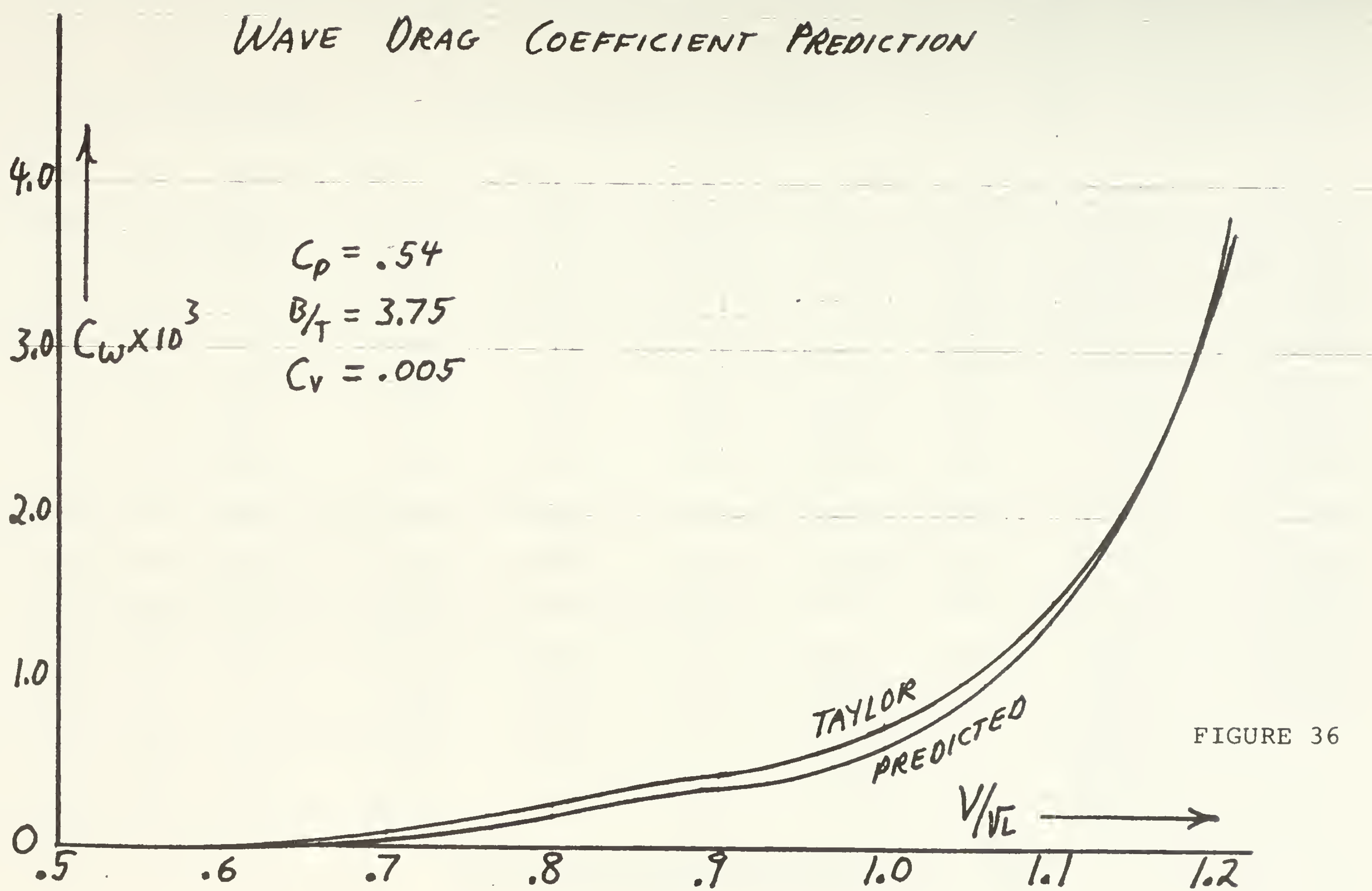

WAVE DRAG COEFFICIENT PREDICTION
$C_p = .54$
$B/T = 3.75$
$C_v = .005$
$C_w \times 10^3$
4.0
3.0
2.0
1.0
0
.5
.6
.7
.8
.9
1.0
1.1
1.2
TAYLOR
PREDICTED
$V/\sqrt{L}$

FIGURE 36

LWL = 190.00   B = 33.74   T = 14.99   DISPL = 47683.1   CP = 0.54271   CM = 0.91407

CB = 0.49607   CV = 0.00695   S = 7773.   CS = 2.5823

S/LWL**2 = 0.21531070   FO + F1*DISPL/(LWL**3) =0.00010092

SLR	F	DISPL *	CP *	CM *	CB *	CV *	CCR	LCB *	F2
0.50	0.149	15417.	0.5986	0.2679	0.1604	0.002248	0.5400	0.0075	0.000000
0.55	0.164	17871.	0.5918	0.3142	0.1859	0.002606	0.5400	0.0060	0.000000
0.60	0.179	20227.	0.5858	0.3592	0.2104	0.002949	0.5400	0.0047	0.000000
0.65	0.193	22444.	0.5806	0.4022	0.2335	0.003272	0.5500	0.0037	0.201087
0.70	0.208	24499.	0.5762	0.4424	0.2549	0.003572	0.5600	0.0028	0.337537
0.75	0.223	26385.	0.5724	0.4796	0.2745	0.003847	0.6200	0.0020	1.164045
0.80	0.238	28103.	0.5692	0.5137	0.2924	0.004097	0.6900	0.0013	1.923824
0.85	0.253	29662.	0.5664	0.5448	0.3086	0.004325	0.8000	0.0008	2.993321
0.90	0.268	31073.	0.5640	0.5731	0.3233	0.004530	0.9300	0.0003	4.091615
0.95	0.283	32347.	0.5620	0.5998	0.3365	0.004716	1.0400	-0.0001	4.840487
1.00	0.298	33498.	0.5602	0.6221	0.3485	0.004884	1.1500	-0.0004	5.506555
1.05	0.313	34538.	0.5586	0.6432	0.3593	0.005035	1.4800	-0.0007	7.982234
1.10	0.327	35478.	0.5573	0.6623	0.3691	0.005172	2.0	-0.0010	
1.15	0.342	36330.	0.5561	0.6797	0.3780	0.005297		-0.0012	
1.20	0.357	37102.	0.5550	0.6954	0.3860	0.005409	5.3	-0.0014	

PREDICTED FORM DRAG COEFFICIENT = .469
FORM DRAG COEFFICIENT FROM MODEL TEST = .540

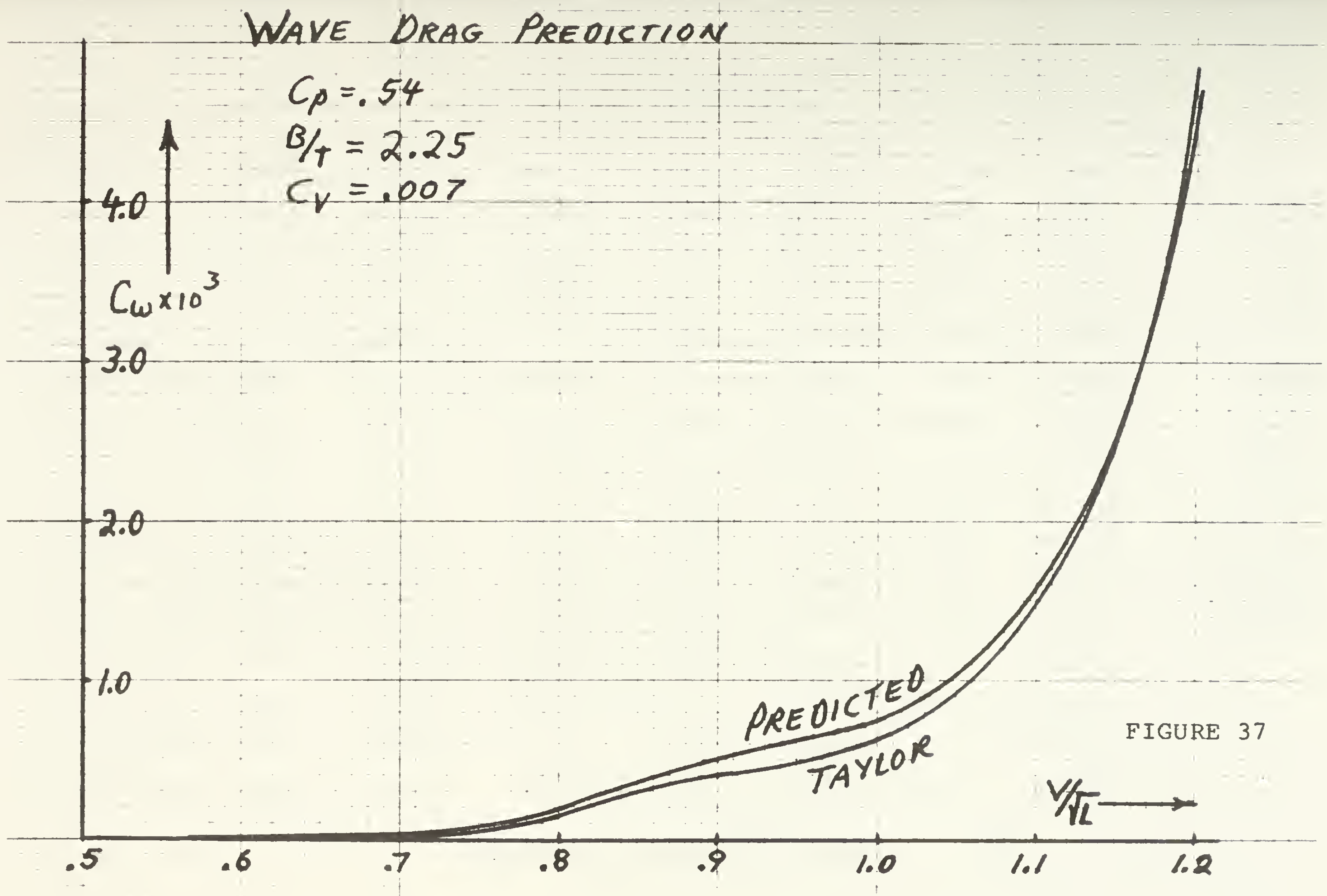

WAVE DRAG PREDICTION
$C_p = .54$
$B/T = 2.25$
$C_V = .007$
$C_w \times 10^3$
4.0
3.0
2.0
1.0
PREDICTED
TAYLOR
$V/\sqrt{L}$
.5
.6
.7
.8
.9
1.0
1.1
1.2

FIGURE 37

LWL = 190.00 B = 43.56 T = 11.61 DISPL = 47683.1 CP = 0.54271 CM = 0.91407

CB = 0.49607 CV = 0.00695 S = 7759. CS = 2.5777

S/LWL**2 = 0.21492200 FC = F1*DISPL/(LWL**3) =0.00015316

SLR	F	DISPL *	CP *	CM *	CB *	CV *	CCR	LCB *	F2
0.50	0.149	18739.	0.5895	0.3307	0.1949	0.002732	0.7700	0.0055	0.000000
0.55	0.164	21351.	0.5831	0.3809	0.2221	0.003113	0.7700	0.0042	0.000000
0.60	0.179	23768.	0.5777	0.4280	0.2473	0.003465	0.7700	0.0031	0.000000
0.65	0.193	25968.	0.5732	0.4713	0.2702	0.003786	0.7800	0.0022	0.149948
0.70	0.208	27950.	0.5694	0.5107	0.2908	0.004075	0.8000	0.0014	0.388281
0.75	0.223	29726.	0.5663	0.5461	0.3093	0.004334	0.8600	0.0008	1.029824
0.80	0.238	31311.	0.5636	0.5779	0.3257	0.004565	0.9700	0.0003	2.062702
0.85	0.253	32723.	0.5614	0.6064	0.3404	0.004771	1.1300	-0.0002	3.399350
0.90	0.268	33981.	0.5595	0.6319	0.3535	0.004954	1.2000	-0.0006	3.765295
0.95	0.283	35102.	0.5578	0.6547	0.3652	0.005118	1.2600	-0.0009	4.020942
1.00	0.298	36103.	0.5564	0.6751	0.3756	0.005264	1.4000	-0.0011	4.887086
1.05	0.313	36998.	0.5552	0.6933	0.3849	0.005394		-0.0014	
1.10	0.327	37801.	0.5541	0.7097	0.3933	0.005511	2.8	-0.0016	
1.15	0.342	38522.	0.5531	0.7245	0.4008	0.005616		-0.0018	
1.20	0.357	39170.	0.5523	0.7378	0.4075	0.005711	6.0	-0.0019	

PREDICTED FORM DRAG COEFFICIENT = .713
FORM DRAG COEFFICIENT FROM MODEL TEST = .770

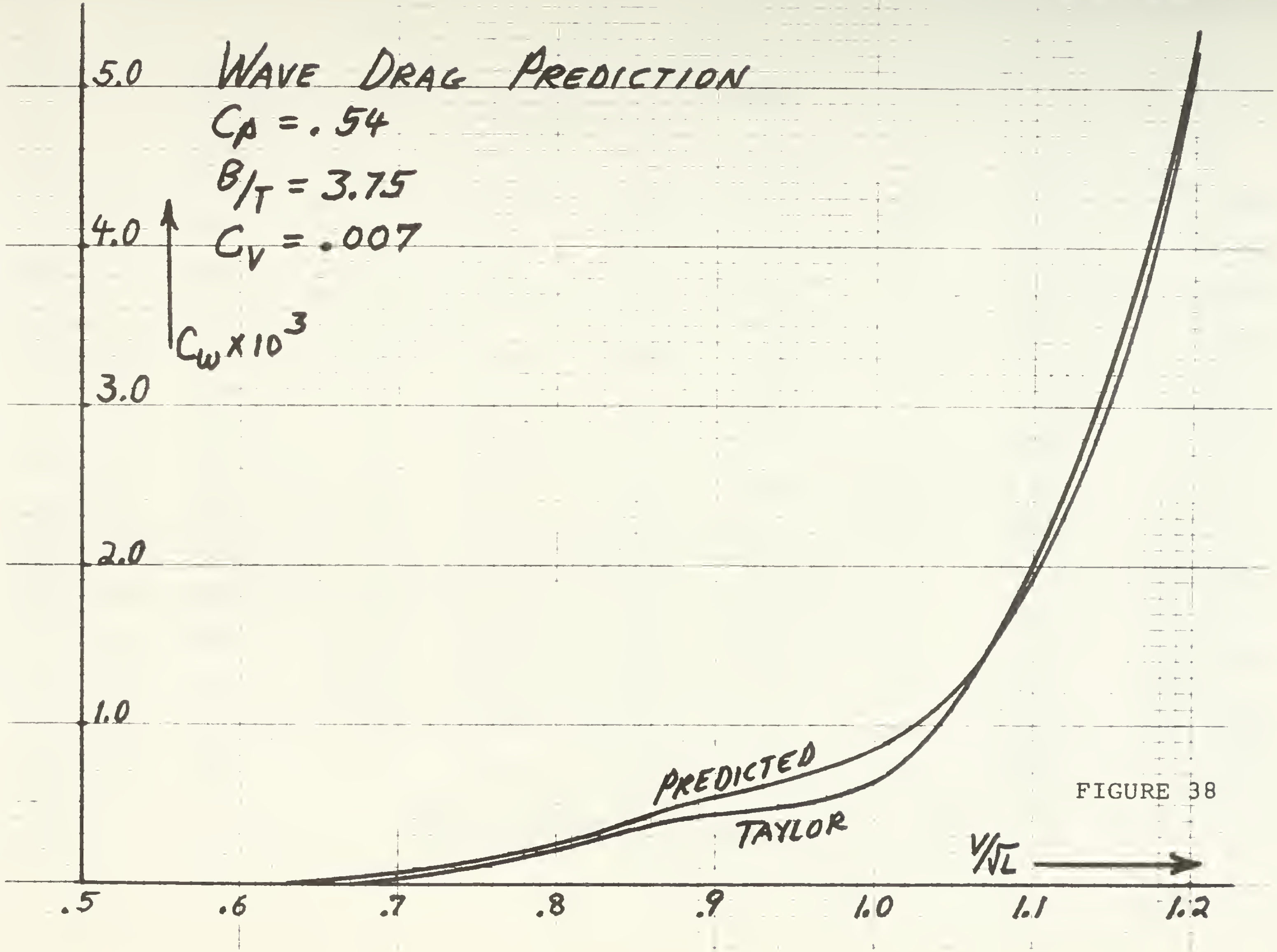

WAVE DRAG PREDICTION
$C_P = .54$
$B/T = 3.75$
$C_V = .007$
$C_W \times 10^3$
5.0
4.0
3.0
2.0
1.0
.5
.6
.7
.8
.9
1.0
1.1
1.2
$V/\sqrt{L}$
PREDICTED
TAYLOR

FIGURE 38

LWL = 190.00 B = 12.10 T = 5.38 DISPL = 6819.3 CP = 0.60361 CM = 0.91407

CB = 0.55174 CV = 0.00099 S = 2900. CS = 2.5475

S/LWL**2 = 0.08032387 FO + FI*DISPL/(LWL**3) =0.00001879

SLR	F	DISPL *	CP *	CM *	CB *	CV *	CCR	LCB *	F2
0.50	0.149	4152.	0.6269	0.5358	0.3359	0.000605	0.2400	0.0016	0.000000
0.55	0.164	4490.	0.6232	0.5829	0.3633	C.000655	0.2400	0.0010	0.000000
0.60	0.179	4776.	0.6202	0.6230	0.3864	C.000696	0.2400	0.0004	0.000000
0.65	0.193	5017.	0.6179	0.657C	0.4059	0.000731	0.2400	0.0000	0.000000
0.70	0.208	5222.	0.6160	0.6858	0.4225	C.000761	0.2400	-0.0003	0.000000
0.75	0.223	5396.	0.6145	0.7105	0.4365	0.000787	0.2400	-0.0006	0.000000
0.80	0.238	5544.	0.6132	0.7315	0.4486	C.000808	0.2500	-0.0008	1.229406
0.85	0.253	5672.	0.6121	0.7497	0.4589	C.000827	0.2700	-0.0010	3.524132
0.90	0.268	5782.	0.6112	0.7654	0.4678	0.000843	0.3100	-0.0012	7.912437
0.95	0.283	5878.	0.6104	0.7790	0.4756	C.000857	0.4000	-0.0013	17.501540
1.00	0.298	5961.	0.6098	0.7909	0.4823	C.000869	0.4600	-0.0014	23.395370
1.05	0.313	6034.	0.6092	0.8014	0.4882	C.000880	0.4600	-0.0015	22.831370
1.10	0.327	6099.	0.6087	0.8106	0.4934	C.C00889	0.4900	-0.0016	25.399130
1.15	0.342	6156.	0.6083	0.8188	0.4981	0.000897	0.5300	-0.0017	28.919580
1.20	0.357	6206.	0.6079	0.826C	0.5022	C.C00905	0.6600	-0.0018	41.202430

PREDICTED FORM DRAG COEFFICIENT = .234
FORM DRAG COEFFICIENT FROM MODEL TEST = .240

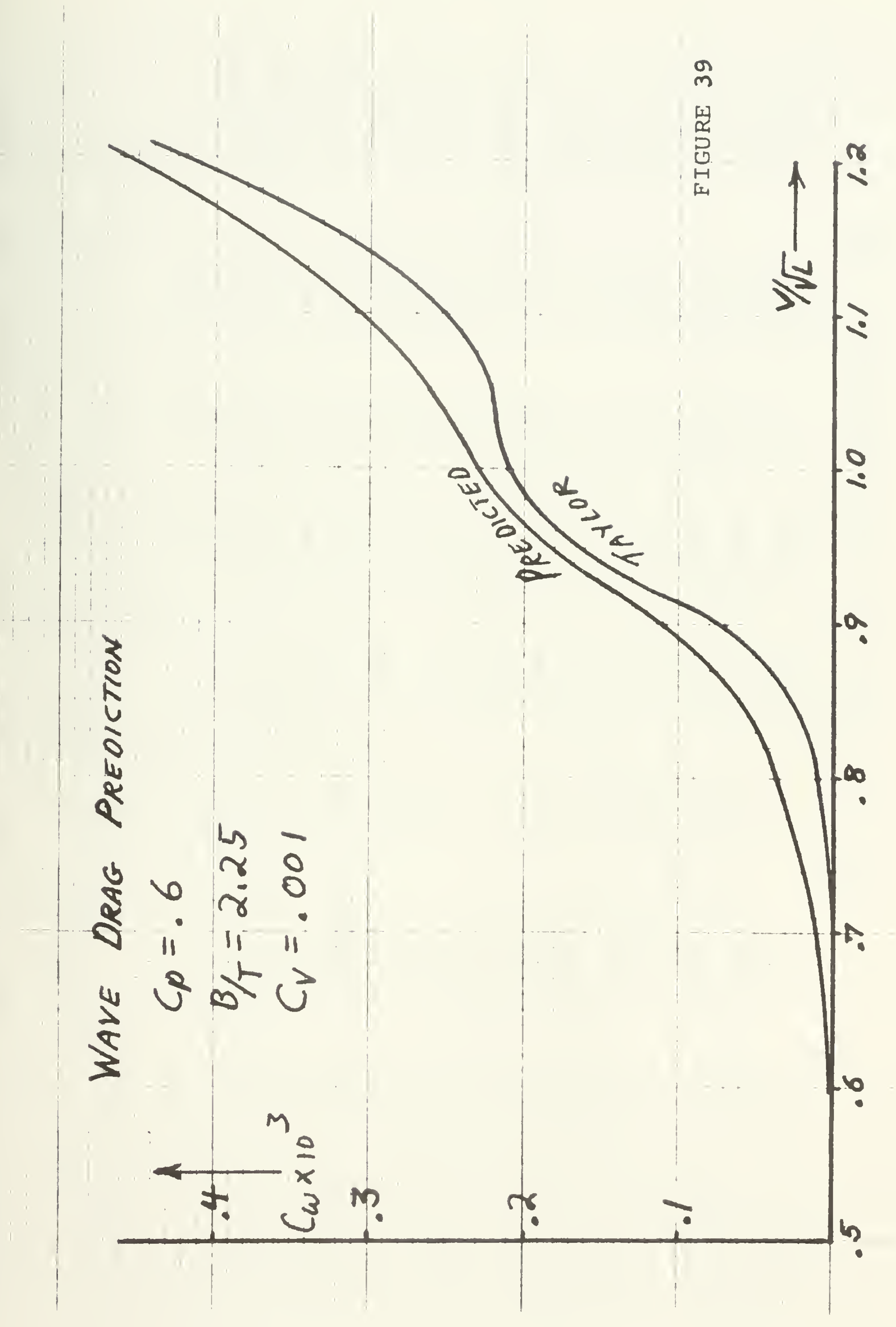

WAVE DRAG PREDICTION
$C_p = .6$
$B/T = 2.25$
$C_V = .001$
$C_w \times 10^3$
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0
1.1
1.2
$V/\sqrt{L}$
PREDICTED
TAYLOR

FIGURE 39

LWL = 190.00 B = 24.20 T = 10.75 DISPL = 27273.4 CP = 0.60361 CM = 0.91407

CB = 0.55174 CV = 0.00398 S = 5821. CS = 2.5571

S/LWL**2 = 0.16124840 F0 + F1*DISPL/(LWL**3) =0.000C6C55

SLR	F	DISPL *	CP *	CM *	CB *	CV *	CCR	LCB *	F2
0.50	0.149	11192.	0.6455	0.3508	0.2264	0.001632	0.3800	0.0051	0.000000
0.55	0.164	12702.	0.6397	0.4017	0.2570	C.001852	0.3800	0.0040	0.000000
0.60	0.179	14087.	0.6348	0.4489	0.2850	0.002054	0.3800	0.0031	0.000000
0.65	0.193	15337.	0.6307	0.4919	0.3103	0.002236	0.3800	0.0023	0.000000
0.70	0.208	16456.	0.6274	0.5306	0.3329	0.002399	0.4300	0.0017	1.400632
0.75	0.223	17453.	0.6246	0.5653	0.3531	C.C02545	0.4700	0.0012	2.241454
0.80	0.238	18338.	0.6222	0.5962	0.3710	C.002674	0.5500	0.0008	3.835105
0.85	0.253	19123.	0.6202	0.6238	C.3868	0.002788	0.7000	0.0004	6.638446
0.90	0.268	19820.	0.6185	0.6483	0.4009	0.002890	0.9700	0.0001	11.394190
0.95	0.283	20439.	0.6170	0.6701	0.4135	0.C02980	1.4300	-0.0002	19.067770
1.C0	0.298	20990.	0.6158	0.6896	0.4246	C.003060	1.8100	-0.0004	24.622490
1.C5	0.313	21482.	0.6147	0.7070	0.4346	C.003132	1.9800	-0.0006	26.302680
1.10	0.327	21921.	0.6137	0.7226	0.4435	C.003196	2.0100	-0.0007	25.731430
1.15	0.342	22316.	0.6129	0.7366	0.4514	0.003254	2.2000	-0.0009	27.724340
1.20	0.357	22670.	0.6121	0.7492	0.4586	C.003305	2.7300	-0.0010	34.687070

PREDICTED FORM DRAG COEFFICIENT = .376
FORM DRAG COEFFICIENT FROM MODEL TEST = .380

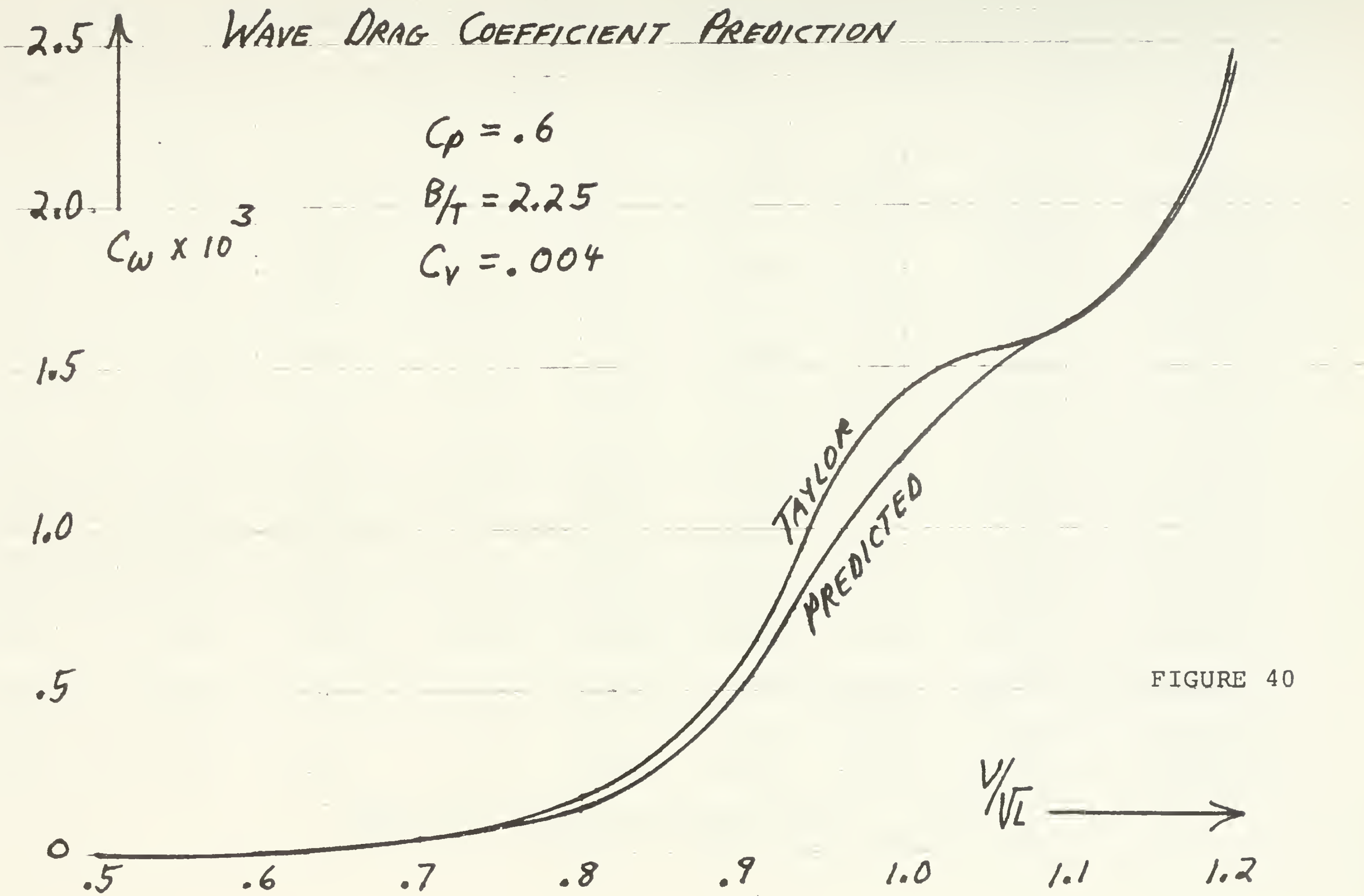

WAVE DRAG COEFFICIENT PREDICTION
$C_p = .6$
$B/T = 2.25$
$C_v = .004$
$C_W \times 10^3$
2.5
2.0
1.5
1.0
.5
0
.5
.6
.7
.8
.9
1.0
1.1
1.2
$V/\sqrt{L}$
TAYLOR
PREDICTED

FIGURE 40

LWL = 190.00 B = 31.24 T = 8.33 DISPL = 27273.0 CP = 0.60361 CM = 0.91407

CB = 0.55173 CV = 0.00398 S = 5876. CS = 2.5812

S/LWL**2 = 0.16276430 FO + F1*DISPL/(LWL**3) =0.0001C036

SLR	F	DISPL *	CP *	CM *	CB *	CV *	CCR	LCB *	F2
0.50	0.149	13219.	0.6378	0.4193	0.2674	C.001927	0.6200	0.0036	0.000000
0.55	0.164	14727.	0.6327	0.4709	0.2979	C.002147	0.6200	0.0027	0.000000
0.60	0.179	16062.	0.6285	0.517C	0.3249	C.002342	0.6200	0.0019	0.000000
0.65	0.193	17235.	0.6252	0.5577	0.3487	C.002513	0.6300	0.0013	0.257798
0.70	0.208	18260.	0.6224	0.5935	0.3694	C.002662	0.6600	0.0008	0.918656
0.75	0.223	19155.	0.6201	0.6249	0.3875	C.002793	0.7100	0.0004	1.878367
0.80	0.238	19936.	0.6182	0.6524	0.4033	0.002907	0.7600	0.0001	2.697338
0.85	0.253	20619.	0.6166	0.6765	0.4171	C.003006	0.8800	-0.0002	4.682738
C.90	0.268	21219.	0.6152	0.6977	0.4293	C.003094	1.1000	-0.0005	8.163549
0.95	0.283	21746.	0.6141	0.7164	0.4399	C.003170	1.4600	-0.0007	13.601960
1.00	0.298	22211.	0.6131	0.7329	0.4493	C.003238	1.7700	-0.0008	17.849940
1.C5	0.313	22623.	0.6122	0.7475	0.4577	0.003298	2.0900	-0.0010	21.993880
1.10	0.327	22989.	0.6115	0.7605	0.4651	C.C03352	2.3900	-0.0011	25.646310
1.15	0.342	23315.	0.6108	0.7722	0.4717	C.003399	2.7500	-0.0013	30.005320
1.20	0.357	23606.	0.6102	0.7826	0.4776	C.003442	3.3000	-0.0014	36.826350

PREDICTED FORM DRAG COEFFICIENT = .617
FORM DRAG COEFFICIENT FROM MODEL TEST = .620

WAVE DRAG COEFFICIENT PREDICTION

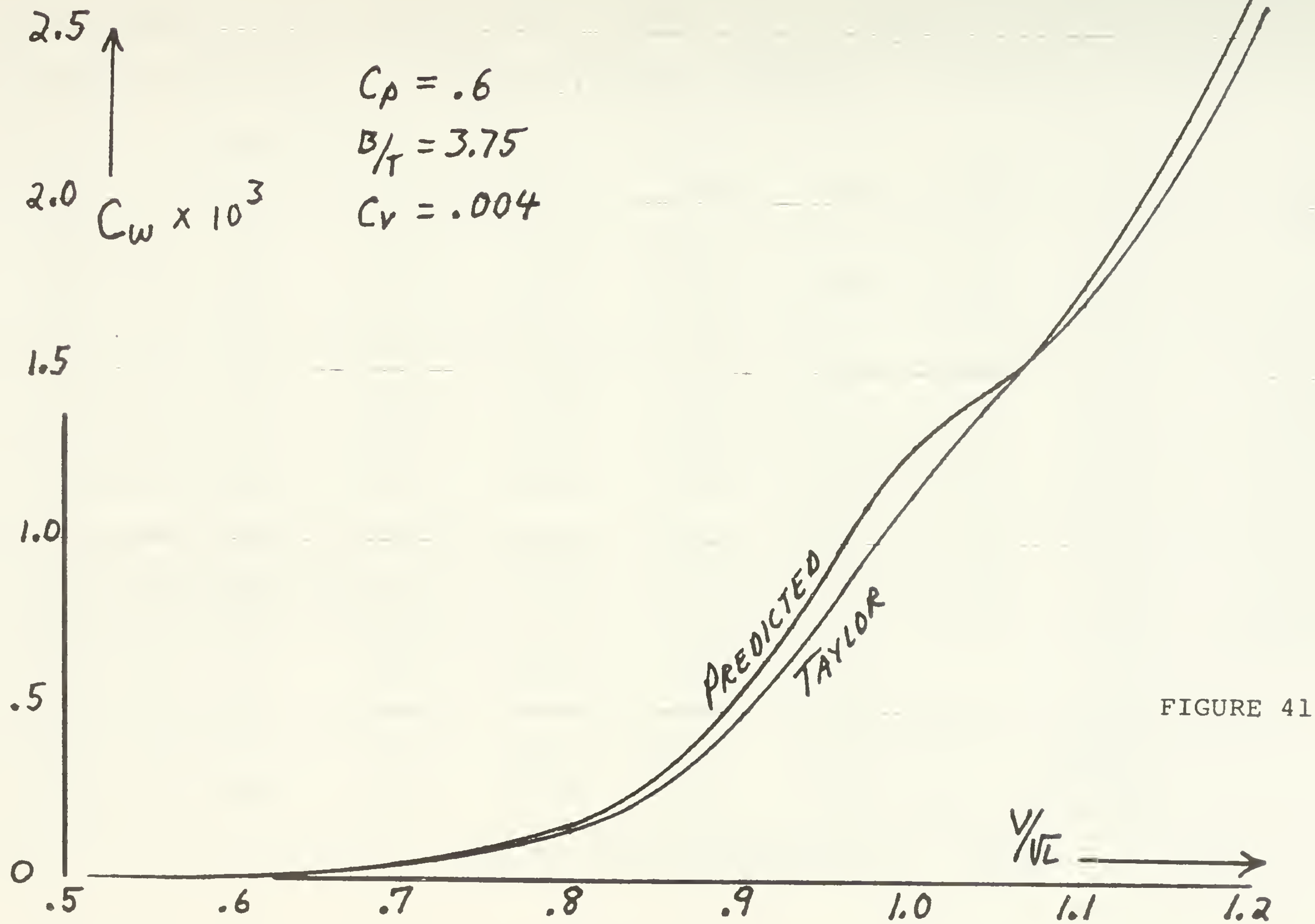


FIGURE 41

LWL = 190.00 B = 32.01 T = 14.23 DISPL = 47728.9 CP = 0.60361 CM = 0.91407

CB = 0.55174 CV = 0.00696 S = 7730. CS = 2.5668

S/LWL**2 = 0.21411570 F0 + F1*DISPL/(LWL**3) =0.00010230

SLR	F	DISPL *	CP *	CM *	CB *	CV *	CCR	LCB *	F2
0.50	0.149	15875.	0.6546	0.2803	0.1835	0.002314	0.5500	0.0069	0.000000
0.55	0.164	18372.	0.6483	0.3276	0.2124	0.002679	0.5600	0.0057	0.298428
0.60	0.179	20756.	0.6428	0.3733	0.2399	0.003026	0.5700	0.0046	0.467633
0.65	0.193	22987.	0.6381	0.4164	0.2657	0.003351	0.5800	0.0037	0.571910
0.70	0.208	25045.	0.6340	0.4566	0.2895	0.003651	0.6200	0.0029	1.124135
0.75	0.223	26926.	0.6306	0.4936	0.3113	0.003926	0.7000	0.0023	2.084112
0.80	0.238	28633.	0.6276	0.5274	0.3310	0.004175	0.7900	0.0018	2.948758
0.85	0.253	30177.	0.6251	0.5580	0.3488	0.004400	0.9700	0.0013	4.645823
0.90	0.268	31570.	0.6230	0.5858	0.3649	0.004603	1.8500	0.0009	13.139110
0.95	0.283	32825.	0.6211	0.6109	0.3795	0.004786	1.9900	0.0006	13.462280
1.00	0.298	33956.	0.6195	0.6336	0.3925	0.004951	2.2700	0.0003	15.026400
1.05	0.313	34977.	0.6181	0.6541	0.4043	0.005099		0.0000	
1.10	0.327	35897.	0.6169	0.6727	0.4150	0.005234	3.46	-0.0002	
1.15	0.342	36730.	0.6158	0.6895	0.4246	0.005355		-0.0004	
1.20	0.357	37484.	0.6148	0.7048	0.4333	0.005465	4.6	-0.0005	

PREDICTED FORM DRAG COEFFICIENT = .478
FORM DRAG COEFFICIENT FROM MODEL TEST = .550

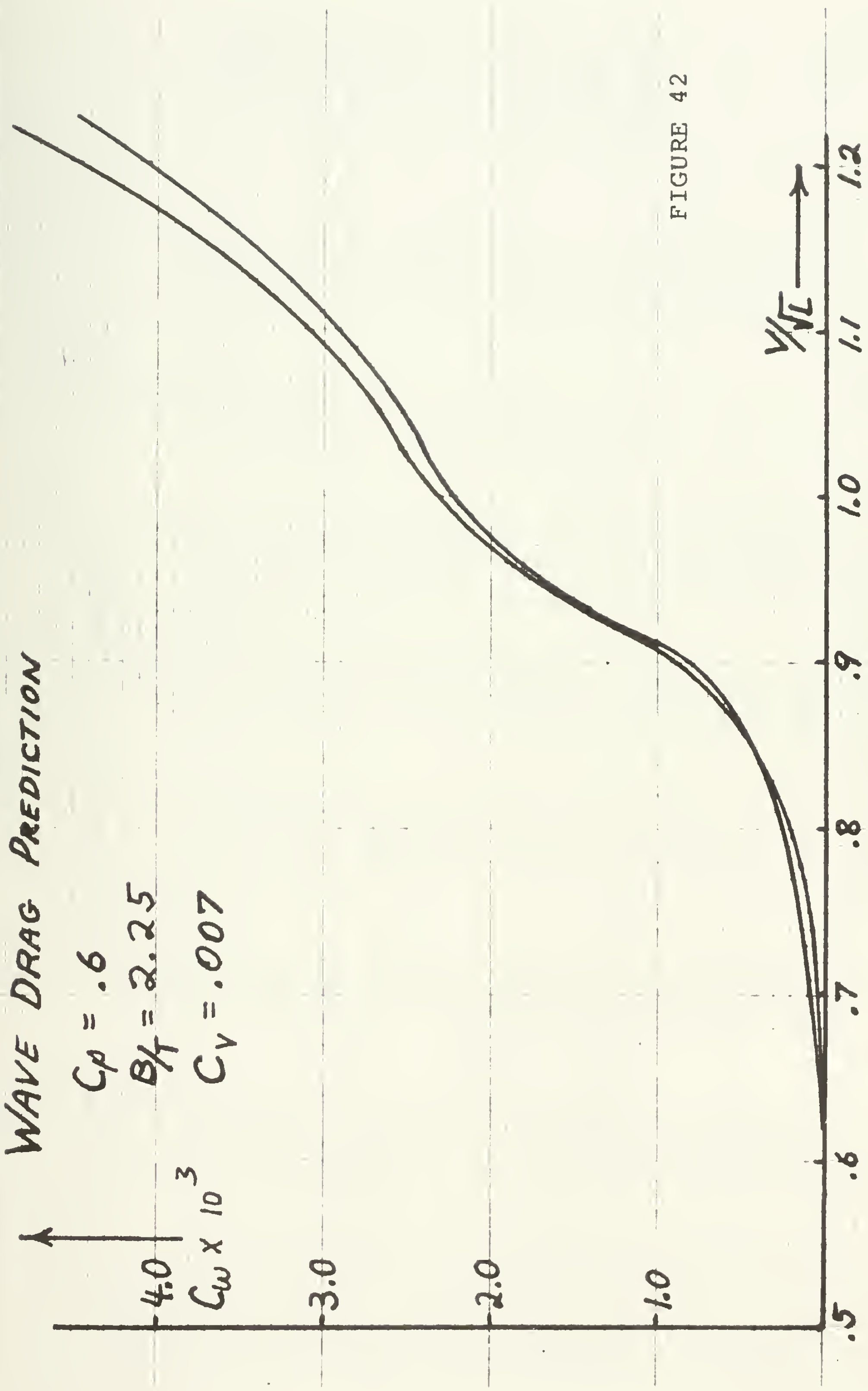

WAVE DRAG PREDICTION
$C_p = .6$
$B/T = 2.25$
$C_V = .007$
$C_w \times 10^3$
4.0
3.0
2.0
1.0
.5
.6
.7
.8
.9
1.0
1.1
1.2
$V/\sqrt{L}$

FIGURE 42

LWL = 190.00 B = 41.32 T = 11.02 DISPL = 47729.5 CP = 0.60361 CM = 0.91407

CB = 0.55174 CV = 0.00696 S = 7806. CS = 2.5921

S/LWL**2 = 0.21622700 FO + F1*DISPL/(LWL**3) =0.00016959

SLR	F	DISPL *	CP *	CM *	CB *	CV *	CCR	LCB *	F2
0.50	0.149	19251.	0.6462	0.3444	0.2225	C.C02807	0.8100	0.0053	0.000000
0.55	0.164	21889.	0.6404	0.3951	0.2530	C.C03191	0.8400	0.0041	0.636964
0.60	0.179	24314.	0.6354	0.4423	0.2811	C.003545	0.8400	0.0032	0.516243
0.65	0.193	2651C.	0.6313	0.4854	0.3065	C.003865	0.8800	0.0024	1.013201
0.70	0.208	28482.	0.6279	0.5243	0.3292	0.004152	0.9500	0.0018	1.755611
0.75	0.223	30240.	0.6250	0.5593	C.3496	C.004409	1.0400	0.0013	2.558478
0.80	0.238	31805.	0.6226	0.5905	0.3677	C.C04637	1.1000	0.0009	2.916346
0.85	0.253	33195.	0.6206	0.6183	0.3837	C.C04840	1.2300	0.0005	3.877315
0.90	0.268	34431.	0.6188	0.6432	0.3980	C.005020	1.5100	0.0002	6.006783
0.95	0.283	35530.	0.6173	0.6653	0.4107	C.005180	2.0000	-0.0001	9.589562
1.00	0.298	36509.	0.6161	0.6851	0.4220	C.C05323	2.6700	-0.0003	14.195380
1.05	0.313	37383.	0.6149	0.7027	0.4321	0.005450		-0.0005	
1.10	0.327	38166.	0.6140	0.7186	0.4412	C.005564	3.8	-0.0007	
1.15	0.342	38868.	0.6131	0.7328	0.4493	C.005667		-0.0008	
1.20	0.357	39500.	0.6123	0.7457	0.4566	C.005759	5.6	-0.0010	

PREDICTED FORM DRAG COEFFICIENT = .784
FORM DRAG COEFFICIENT FROM MODEL TEST = .810

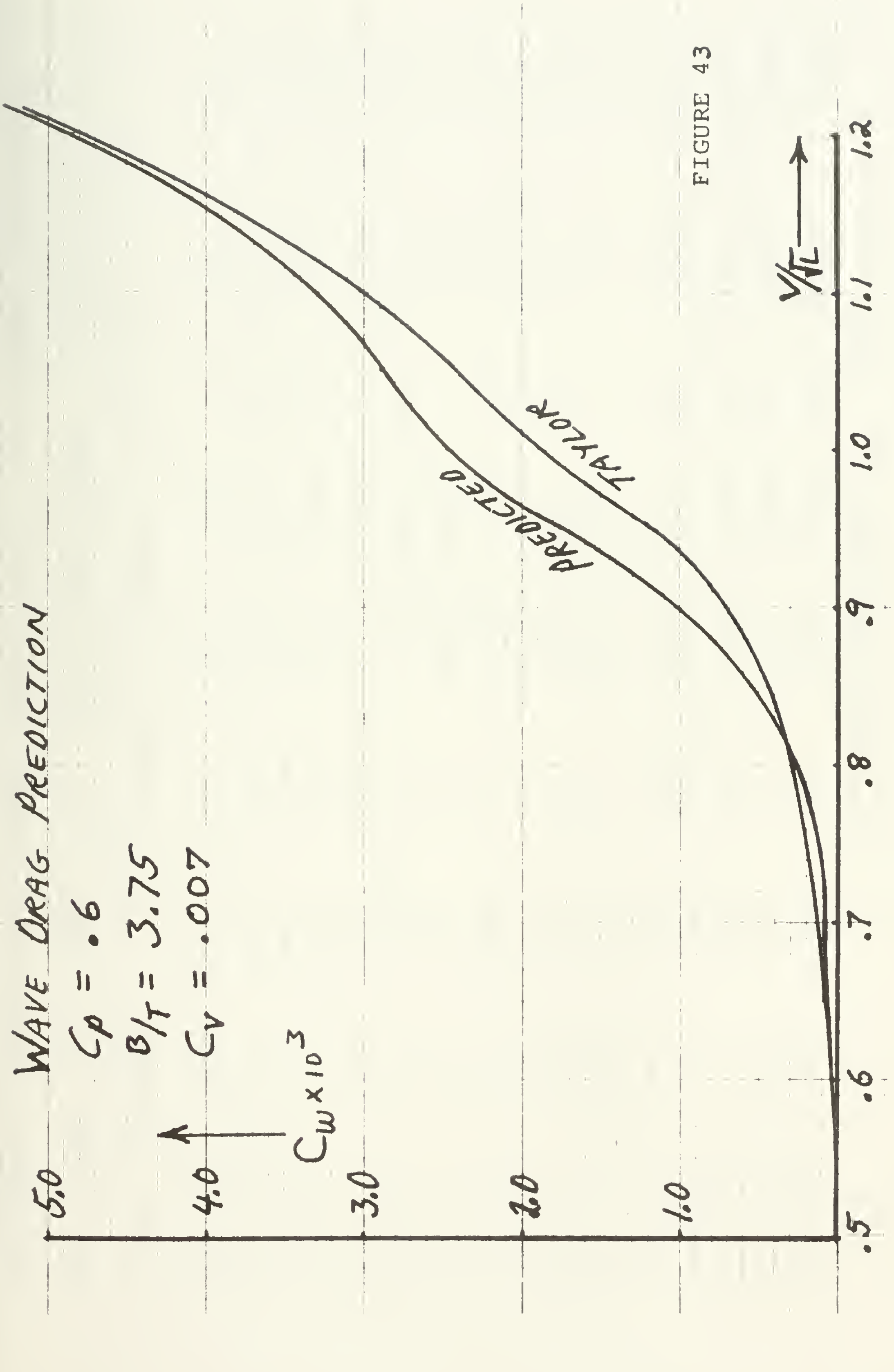

WAVE DRAG PREDICTION
$C_p = .6$
$B/T = 3.75$
$C_V = .007$
$C_W \times 10^3$
5.0
4.0
3.0
2.0
1.0
.5
.6
.7
.8
.9
1.0
1.1
1.2
$V/\sqrt{L}$
TAYLOR
PREDICTED

FIGURE 43

LWL = 190.00 B = 11.62 T = 5.17 DISPL = 6814.7 CP = 0.65360 CM = 0.91407

CB = 0.59743 CV = 0.00099 S = 2896. CS = 2.5451

S/LWL**2 = 0.08022255 FO + F1*DISPL/(LWL**3) =0.00001984

SLR	F	DISPL *	CP *	CM *	CB *	CV *	CCR	LCB *	F2
0.50	0.149	4201.	0.6746	0.5460	0.3683	0.000613	0.2300	0.0014	0.000000
0.55	0.164	4536.	0.6712	0.5924	0.3977	0.000661	0.2300	0.0008	0.000000
0.60	0.179	4818.	0.6686	0.6318	0.4224	0.000702	0.2300	0.0003	0.000000
0.65	0.193	5056.	0.6665	0.6650	0.4432	0.000737	0.2400	-0.0000	1.476523
0.70	0.208	5256.	0.6648	0.6932	0.4608	0.000766	0.2400	-0.0003	1.365942
0.75	0.223	5427.	0.6634	0.7172	0.4758	0.000791	0.2400	-0.0006	1.281441
0.80	0.238	5573.	0.6622	0.7377	0.4885	0.000812	0.2700	-0.0008	4.861524
0.85	0.253	5697.	0.6612	0.7554	0.4995	0.000831	0.3500	-0.0009	13.952210
0.90	0.268	5805.	0.6604	0.7706	0.5089	0.000846	0.4800	-0.0011	27.998220
0.95	0.283	5899.	0.6597	0.7838	0.5171	0.000860	0.6200	-0.0012	42.304320
1.00	0.298	5980.	0.6592	0.7953	0.5243	0.000872	0.7500	-0.0013	54.879330
1.05	0.313	6051.	0.6586	0.8055	0.5305	0.000882	0.7900	-0.0014	57.714720
1.10	0.327	6114.	0.6582	0.8144	0.5360	0.000891	0.7900	-0.0014	56.534400
1.15	0.342	6170.	0.6578	0.8223	0.5409	0.000900	0.7800	-0.0015	54.528990
1.20	0.357	6219.	0.6575	0.8293	0.5452	0.000907	0.8400	-0.0016	59.521490

PREDICTED FORM DRAG COEFFICIENT = .247
FORM DRAG COEFFICIENT FROM MODEL TEST = .230

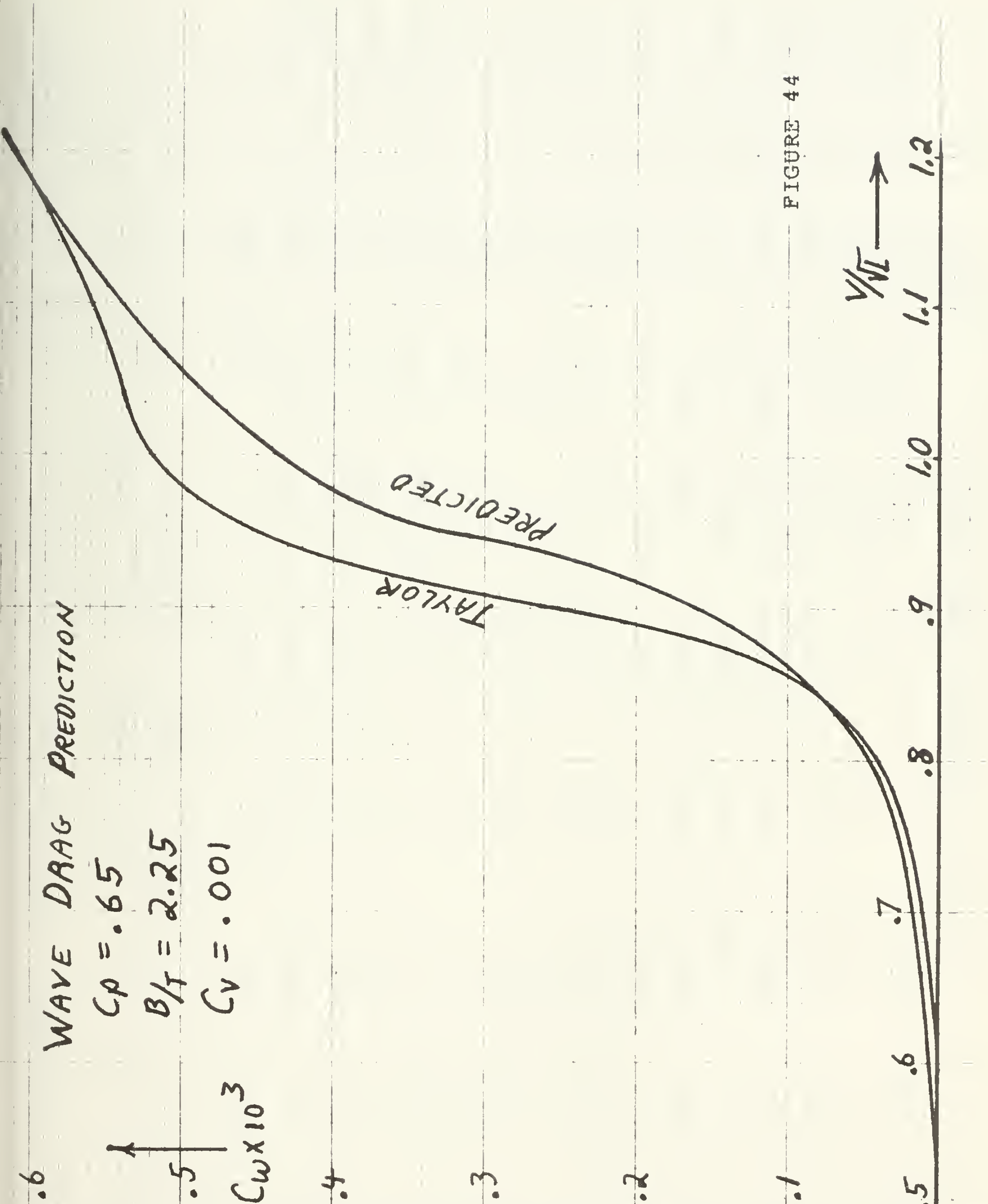

WAVE DRAG PREDICTION
$C_p = .65$
$B/T = 2.25$
$C_v = .001$
$C_w \times 10^3$
.6
.5
.4
.3
.2
.1
.5
.6
.7
.8
.9
1.0
1.1
1.2
$V/\sqrt{L}$
PREDICTED
TAYLOR

FIGURE 44

LWL = 190.00 B = 20.13 T = 8.95 DISPL = 20446.5 CP = 0.65360 CM = 0.91407

CB = 0.59743 CV = 0.00298 S = 5029. CS = 2.5516

S/LWL**2 = 0.13931290 F0 + F1*DISPL/(LWL**3) =0.00004766

SLR	F	DISPL *	CP *	CM *	CB *	CV *	CCR	LCB *	F2
0.50	0.149	9408.	0.6874	0.3999	0.2749	0.001372	0.3400	0.0036	0.000000
0.55	0.164	10547.	0.6825	0.4516	0.3082	0.001538	0.3400	0.0027	0.000000
0.60	0.179	11567.	0.6784	0.4982	0.3380	0.001686	0.3400	0.0020	0.000000
0.65	0.193	12470.	0.6751	0.5397	0.3644	0.001818	0.3400	0.0014	0.000000
0.70	0.208	13265.	0.6724	0.5765	0.3876	0.001934	0.3800	0.0010	1.489893
0.75	0.223	13963.	0.6701	0.6088	0.4080	0.002036	0.4800	0.0006	4.706328
0.80	0.238	14576.	0.6682	0.6374	0.4259	0.002125	0.6100	0.0002	8.329691
0.85	0.253	15113.	0.6666	0.6625	0.4416	0.002203	0.8000	-0.0000	13.199050
0.90	0.268	15587.	0.6653	0.6846	0.4554	0.002272	1.0800	-0.0003	19.963130
0.95	0.283	16004.	0.6641	0.7042	0.4676	0.002333	1.6200	-0.0004	32.752470
1.00	0.298	16374.	0.6631	0.7215	0.4784	0.002387	2.2800	-0.0006	47.426040
1.05	0.313	16701.	0.6623	0.7369	0.4880	0.002435	2.4400	-0.0008	49.342490
1.10	0.327	16993.	0.6615	0.7506	0.4965	0.002478	2.4500	-0.0009	47.890090
1.15	0.342	17254.	0.6608	0.7629	0.5041	0.002515	2.4100	-0.0010	45.574640
1.20	0.357	17487.	0.6603	0.7739	0.5110	0.002549	2.6200	-0.0011	48.867950

PREDICTED FORM DRAG COEFFICIENT = .337
FORM DRAG COEFFICIENT FROM MODEL TEST = .340

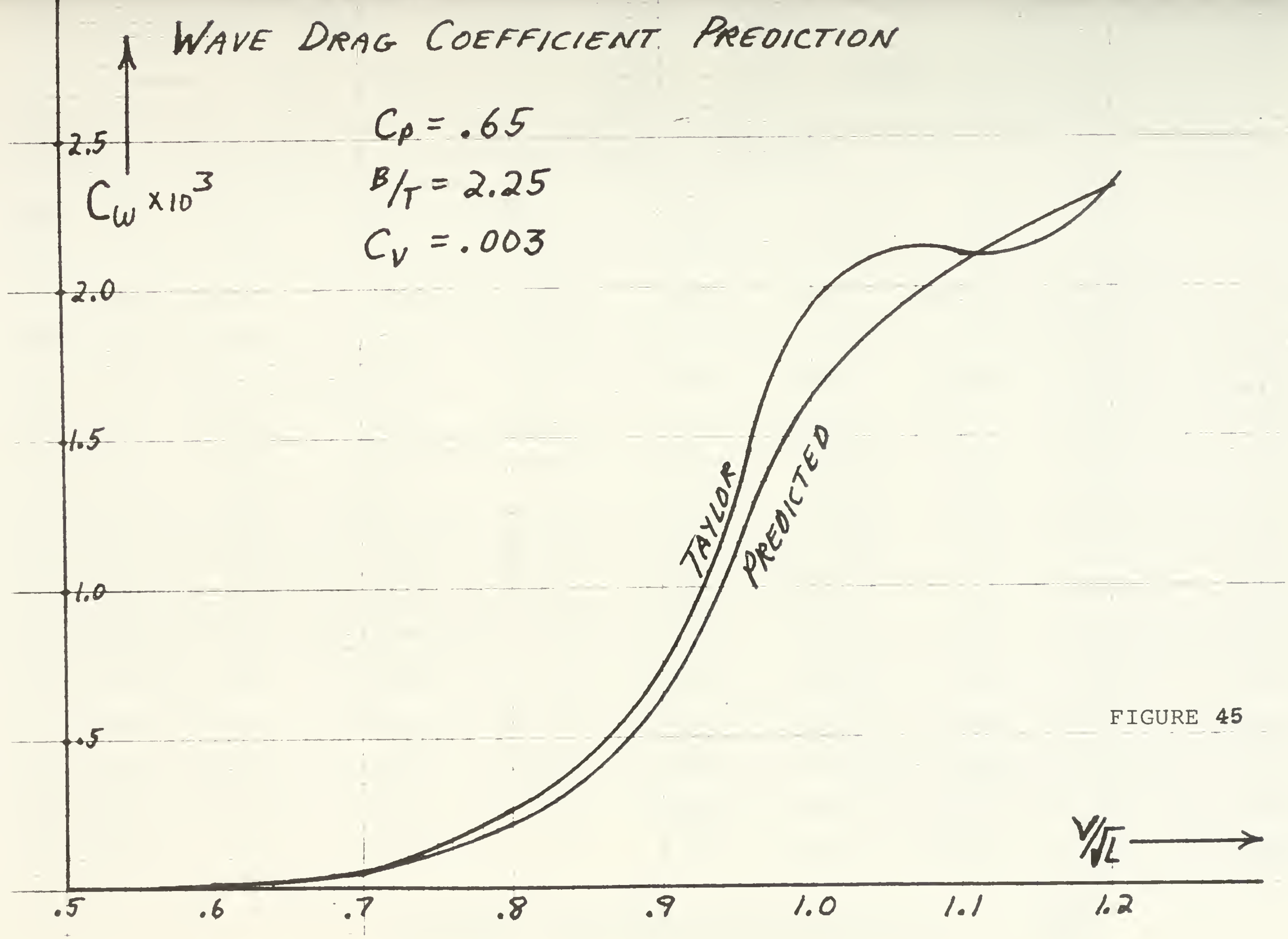

WAVE DRAG COEFFICIENT PREDICTION
$C_p = .65$
$B/T = 2.25$
$C_V = .003$
$C_W \times 10^3$
2.5
2.0
1.5
1.0
.5
TAYLOR
PREDICTED
$V/\sqrt{L}$
.5
.6
.7
.8
.9
1.0
1.1
1.2

FIGURE 45

LWL = 190.00 B = 30.01 T = 8.00 DISPL = 27261.9 CP = 0.65360 CM = 0.91407

CB = 0.59743 CV = 0.00397 S = 5919. CS = 2.6009

S/LWL**2 = 0.16397470 F0 + F1*DISPL/(LWL**3) =0.00010906

SLR	F	DISPL *	CP *	CM *	CB *	CV *	CCR	LCB *	F2
0.50	0.149	13435.	0.6845	0.4301	0.2944	0.001959	0.6500	0.0031	0.000000
0.55	0.164	14940.	0.6798	0.4816	0.3274	0.002178	0.6500	0.0023	0.000000
0.60	0.179	16268.	0.6761	0.5273	0.3565	0.002372	0.6500	0.0016	0.000000
0.65	0.193	17430.	0.6730	0.5676	0.3820	0.002541	0.6800	0.0011	0.761755
0.70	0.208	18444.	0.6705	0.6028	0.4042	0.002689	0.7500	0.0006	2.267787
0.75	0.223	19325.	0.6685	0.6336	0.4235	0.002818	0.8300	0.0003	3.717540
0.80	0.238	20096.	0.6667	0.6605	0.4404	0.002930	0.8900	-0.0000	4.584553
0.85	0.253	20768.	0.6653	0.6841	0.4551	0.003028	1.0800	-0.0002	7.691047
0.90	0.268	21356.	0.6641	0.7048	0.4680	0.003114	1.4600	-0.0005	13.700370
0.95	0.283	21873.	0.6630	0.7230	0.4793	0.003189	2.1000	-0.0006	23.379830
1.00	0.298	22329.	0.6621	0.7390	0.4893	0.003255	2.7700	-0.0008	32.802000
1.05	0.313	22732.	0.6614	0.7532	0.4982	0.003314	3.2700	-0.0009	39.113580
1.10	0.327	23090.	0.6607	0.7659	0.5060	0.003366	3.5800	-0.0010	42.396540
1.15	0.342	23408.	0.6601	0.7771	0.5130	0.003413	3.8600	-0.0011	45.191980
1.20	0.357	23693.	0.6596	0.7872	0.5192	0.003454	4.2000	-0.0012	48.784400

PREDICTED FORM DRAG COEFFICIENT = .665
FORM DRAG COEFFICIENT FROM MODEL TEST = .640

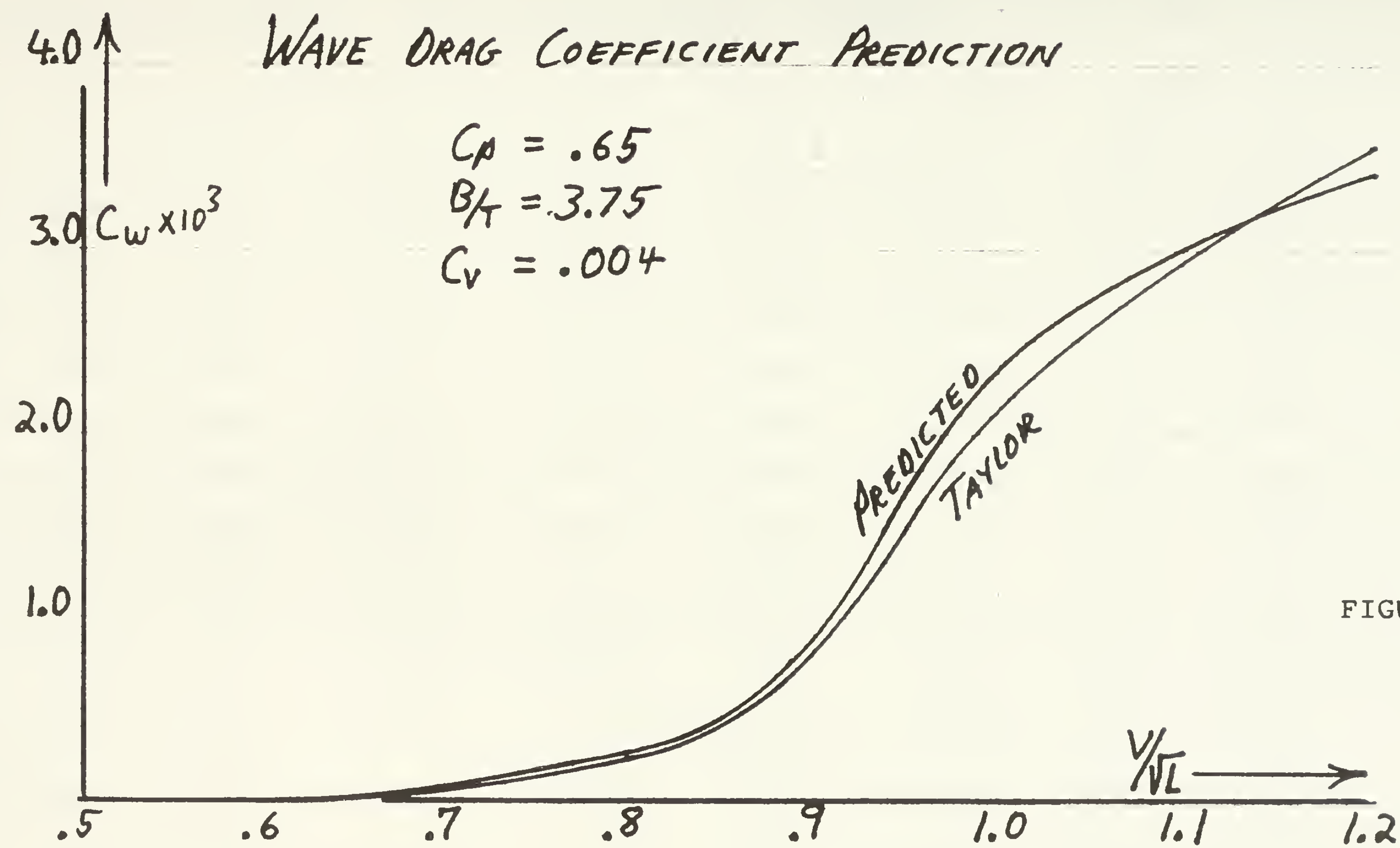

WAVE DRAG COEFFICIENT PREDICTION
$C_p = .65$
$B/T = 3.75$
$C_v = .004$
$C_w \times 10^3$
4.0
3.0
2.0
1.0
.5
.6
.7
.8
.9
1.0
1.1
1.2
$V/\sqrt{L}$
PREDICTED
TAYLOR

FIGURE 46

LWL = 190.00   B = 25.99   T = 11.55   DISPL = 34077.3   CP = 0.65360   CM = 0.91407

CB = 0.59743   CV = 0.00497   S = 6509.   CS = 2.5581

S/LWL**2 = 0.18030670   F0 + F1*DISPL/(LWL**3) =0.00007548

SLR	F	DISPL *	CP *	CM *	CB *	CV *	CCR	LCB *	F2
0.50	0.149	13161.	0.6947	0.3321	0.2307	0.001919	0.4700	0.0050	0.000000
0.55	0.164	15034.	0.6892	0.3824	0.2636	0.002192	0.4700	0.0040	0.000000
0.60	0.179	16770.	0.6845	0.4295	0.2940	0.002445	0.4700	0.0031	0.000000
0.65	0.193	18354.	0.6806	0.4728	0.3218	0.002676	0.4700	0.0024	0.000000
0.70	0.208	19783.	0.6773	0.5121	0.3468	0.002884	0.5400	0.0018	1.517223
0.75	0.223	21065.	0.6745	0.5475	0.3693	0.003071	0.6600	0.0013	3.632302
0.80	0.238	22209.	0.6722	0.5793	0.3894	0.003238	0.8000	0.0009	5.675139
0.85	0.253	23230.	0.6702	0.6077	0.4073	0.003387	1.0100	0.0006	8.488399
0.90	0.268	24140.	0.6685	0.6331	0.4232	0.003519	1.4800	0.0003	14.702220
0.95	0.283	24951.	0.6670	0.6558	0.4374	0.003638	2.4500	0.0000	26.977950
1.00	0.298	25676.	0.6658	0.6761	0.4501	0.003743	3.3700	-0.0002	37.314070
1.05	0.313	26324.	0.6647	0.6943	0.4615	0.003838	3.9200	-0.0004	42.231170
1.10	0.327	26906.	0.6637	0.7107	0.4717	0.003923	4.0500	-0.0005	41.949490
1.15	0.342	27428.	0.6629	0.7254	0.4809	0.003999	4.1000	-0.0007	40.930900
1.20	0.357	27898.	0.6622	0.7387	0.4891	0.004067	4.3700	-0.0008	42.504800

PREDICTED FORM DRAG COEFFICIENT = .419
FORM DRAG COEFFICIENT FROM MODEL TEST = .470

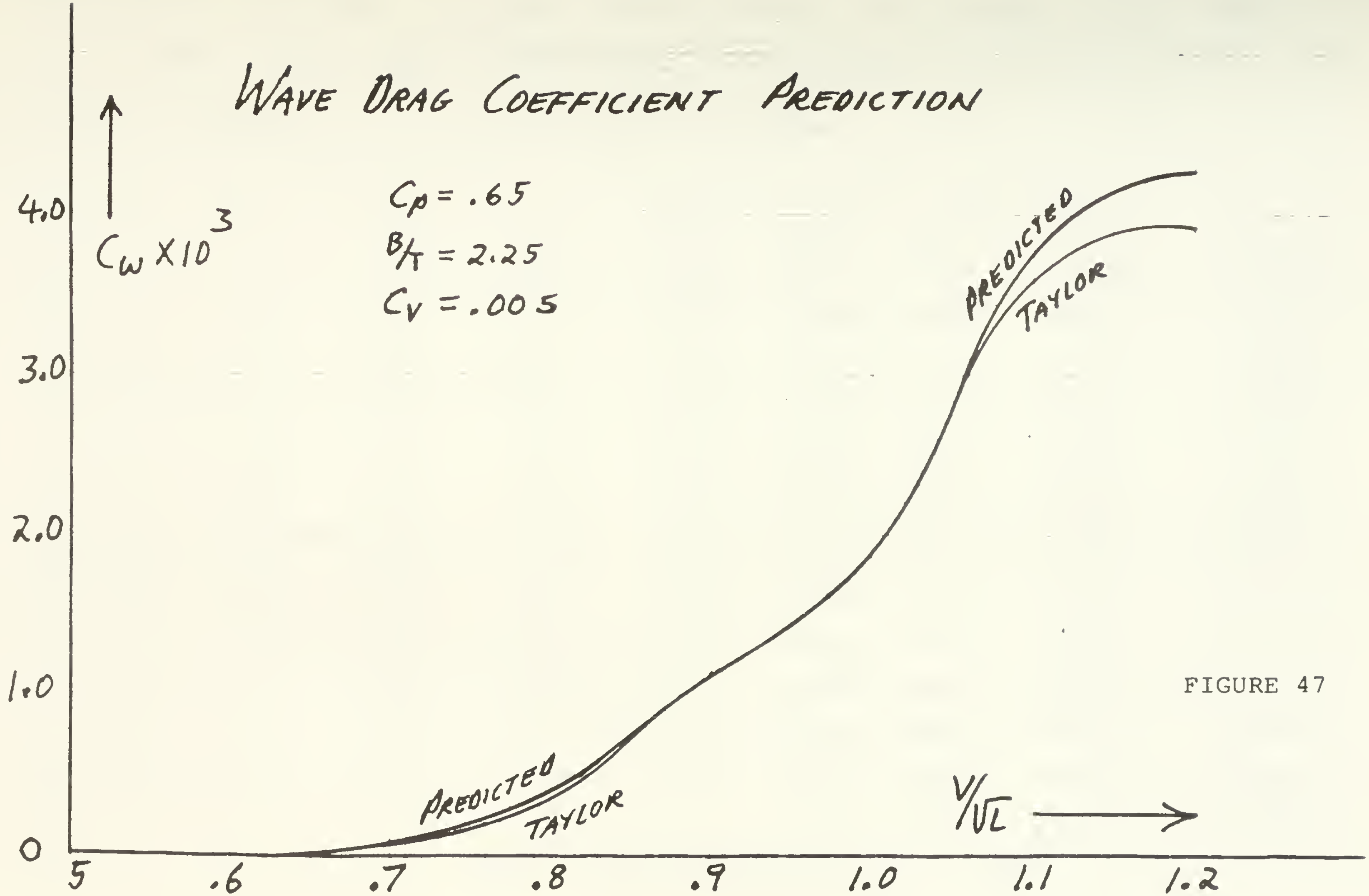

WAVE DRAG COEFFICIENT PREDICTION
$C_p = .65$
$B/T = 2.25$
$C_V = .005$
$C_W \times 10^3$
4.0
3.0
2.0
1.0
0
5
.6
.7
.8
.9
1.0
1.1
1.2
$V/\sqrt{L}$
PREDICTED
TAYLOR
PREDICTED
TAYLOR

FIGURE 47

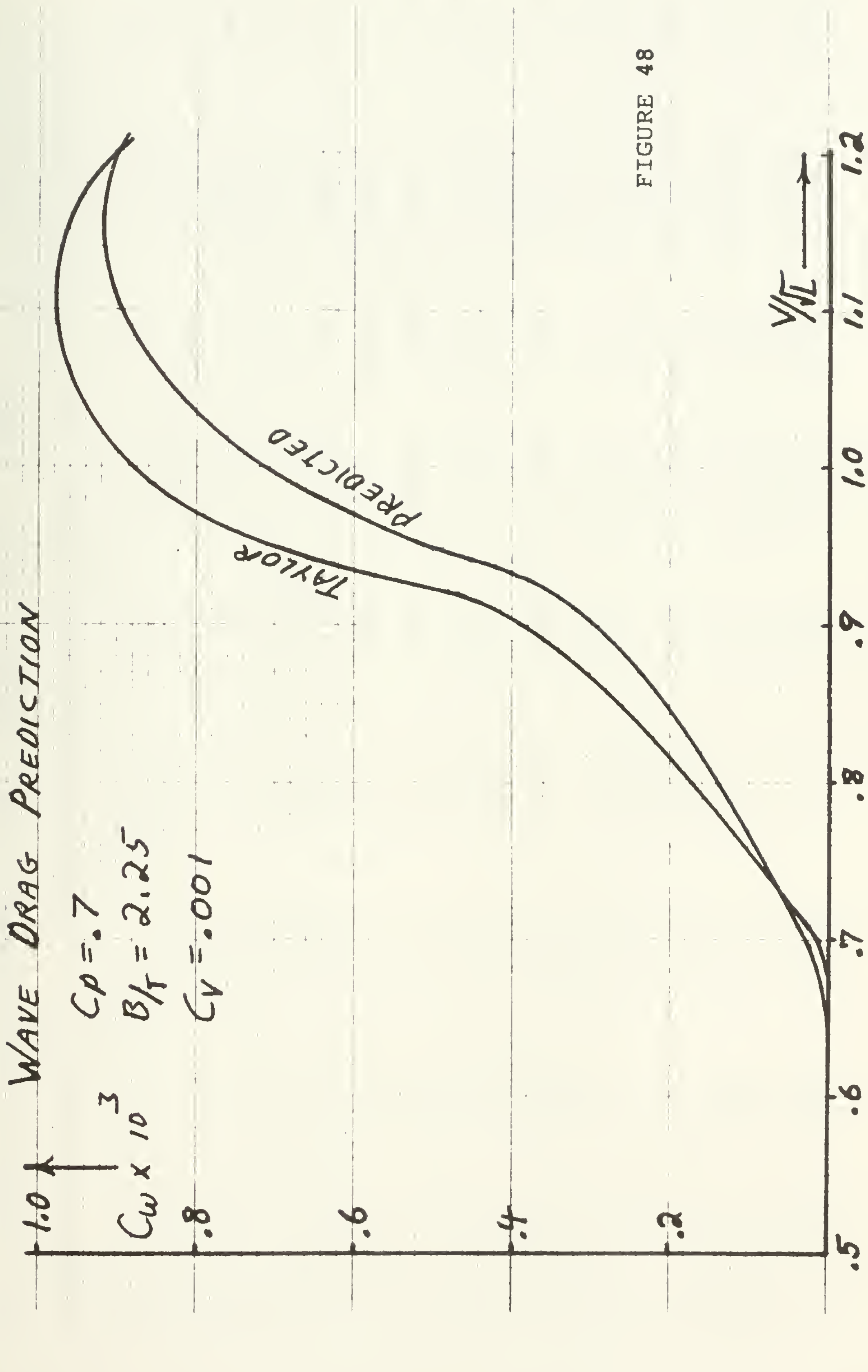
LWL = 190.00 B = 11.20 T = 4.98 DISPL = 68C7.7 CP = 0.70307 CM = 0.91407

CB = 0.64265 CV = 0.00095 S = 2899. CS = 2.5487

S/LWL**2 = 0.08029598 FO + F1*DISPL/(LWL**3) =0.00002086

SLR	F	DISPL *	CP *	CM *	CB *	CV *	CCR	LCB *	F2
0.50	0.149	4243.	0.7214	0.5552	0.4005	0.000619	0.2300	0.0013	0.000000
0.55	0.164	4574.	0.7184	0.6011	0.4318	C.000667	0.2300	0.0008	0.000000
0.60	0.179	4853.	0.7161	0.6397	0.4581	0.000707	0.2300	0.0004	0.000000
0.65	0.193	5087.	0.7143	0.6723	C.4802	0.000742	0.2300	0.0001	0.000000
0.70	0.208	5284.	0.7128	0.6999	0.4988	0.000770	0.2400	-0.0001	1.352830
0.75	0.223	5452.	0.7116	0.7233	0.5147	0.000795	0.3000	-0.0003	8.896783
0.80	0.238	5595.	0.7106	0.7433	0.5281	C.000816	0.4000	-0.0005	20.517500
0.85	0.253	5717.	0.7097	0.7604	0.5397	0.000834	0.5100	-0.0006	32.361900
0.90	0.268	5823.	0.7090	0.7752	0.5497	C.000849	0.6300	-0.0007	44.570730
0.95	0.283	5914.	0.7084	0.7881	0.5583	C.C00862	0.8700	-0.0008	69.124640
1.00	0.298	5994.	0.7079	0.7993	0.5658	C.000874	1.1100	-0.0009	92.535700
1.C5	0.313	6063.	0.7075	0.8091	0.5724	C.000884	1.2200	-0.0010	101.720000
1.10	0.327	6125.	0.7071	0.8177	0.5782	0.000893	1.2100	-0.0010	98.683510
1.15	0.342	6179.	0.7067	0.8254	C.5833	C.000901	1.1600	-0.0011	92.010230
1.20	0.357	6227.	0.7064	0.8322	0.5879	C.C00908	1.1300	-0.0011	87.669060

PREDICTED FORM DRAG COEFFICIENT = .260
FORM DRAG COEFFICIENT FROM MODEL TEST = .230



WAVE DRAG PREDICTION
Cp = .7
B/T = 2.25
Cv = .001
Cw x 10 3
1.0
.8
.6
.4
.2
.5
.6
.7
.8
.9
1.0
1.1
1.2
V/√L
TAYLOR
PREDICTED

FIGURE 48

LWL = 190.00 B = 28.92 T = 7.71 DISPL = 27230.6 CP = 0.70307 CM = 0.91407

CB = 0.64265 CV = 0.00397 S = 5971. CS = 2.6252

S/LWL**2 = 0.16540920 F0 + F1*DISPL/(LWL**3) =0.00011759

SLR	F	DISPL *	CP *	CM *	CB *	CV *	CCR	LCB *	F2
0.50	0.149	13616.	0.7300	0.4402	0.3213	0.001985	0.7100	0.0028	0.000000
0.55	0.164	15117.	0.7259	0.4915	0.3568	0.002204	0.7100	0.0021	0.000000
0.60	0.179	16437.	0.7226	0.5368	0.3879	0.002396	0.7100	0.0015	0.000000
0.65	0.193	17589.	0.7200	0.5766	0.4151	0.002564	0.7500	0.0011	1.006124
0.70	0.208	18591.	0.7178	0.6113	0.4388	0.002711	0.8600	0.0007	3.377151
0.75	0.223	19462.	0.7160	0.6415	0.4593	0.002838	1.0200	0.0004	6.368646
0.80	0.238	20221.	0.7145	0.6679	0.4772	0.002948	1.2300	0.0002	9.896895
0.85	0.253	20882.	0.7132	0.6909	0.4928	0.003044	1.4800	-0.0000	13.741740
0.90	0.268	21460.	0.7122	0.7111	0.5065	0.003129	1.9400	-0.0002	20.784040
0.95	0.283	21967.	0.7113	0.7289	0.5184	0.003203	2.8300	-0.0004	34.186930
1.00	0.298	22414.	0.7105	0.7445	0.5290	0.003268	3.9000	-0.0005	49.410750
1.05	0.313	22809.	0.7098	0.7584	0.5383	0.003325	4.7000	-0.0006	59.680080
1.10	0.327	23160.	0.7092	0.7707	0.5466	0.003377	5.1500	-0.0007	64.416610
1.15	0.342	23472.	0.7087	0.7816	0.5539	0.003422	5.4000	-0.0008	66.247290
1.20	0.357	23750.	0.7083	0.7914	0.5605	0.003463	5.6300	-0.0008	67.874980

PREDICTED FORM DRAG COEFFICIENT = .711
FORM DRAG COEFFICIENT FROM MODEL TEST = .710

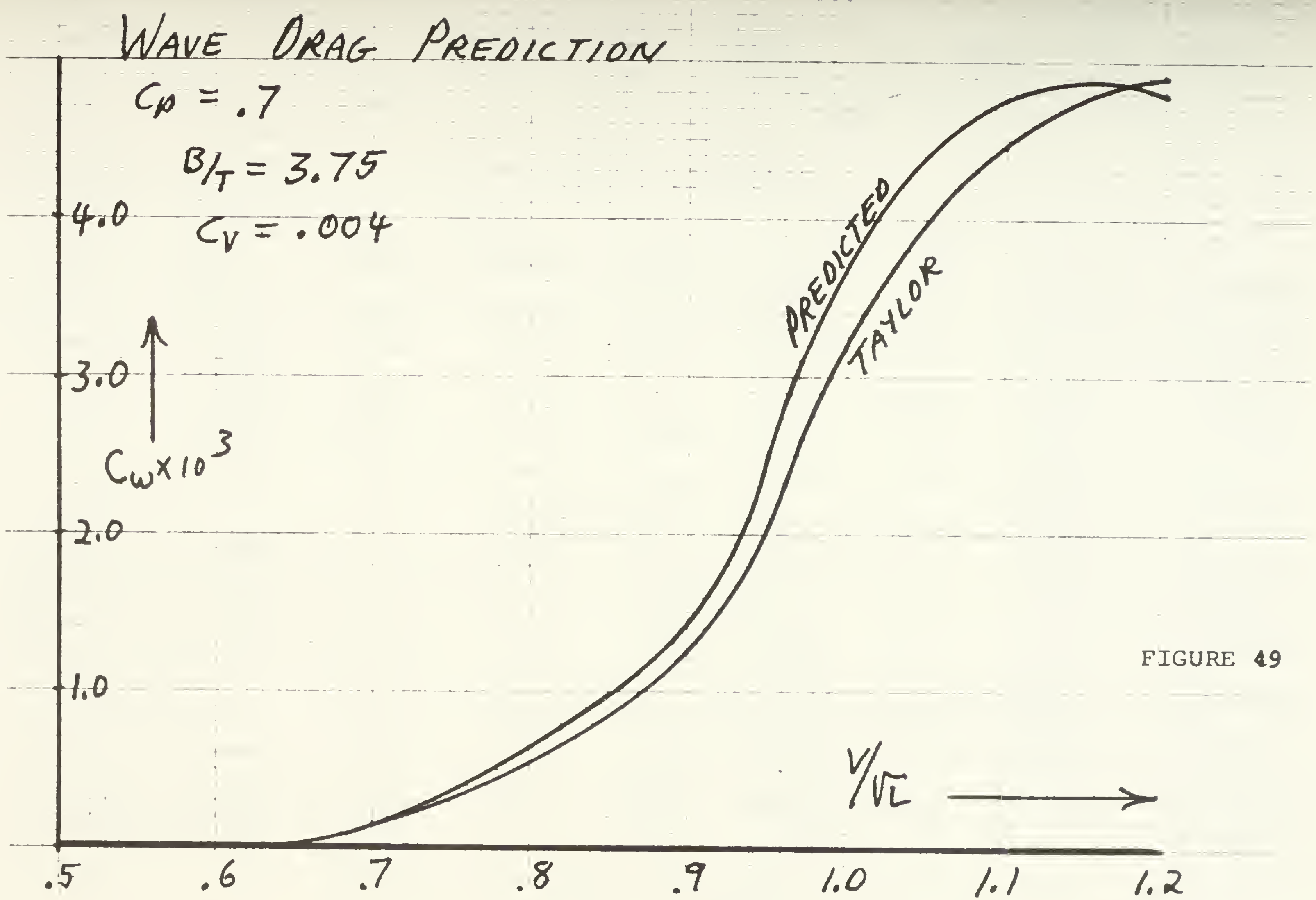

WAVE DRAG PREDICTION
$C_p = .7$
$B/_T = 3.75$
$C_V = .004$
$C_w \times 10^3$
4.0
3.0
2.0
1.0
PREDICTED
TAYLOR
$V/\sqrt{L}$
.5
.6
.7
.8
.9
1.0
1.1
1.2

FIGURE 49

LWL = 190.00 B = 22.40 T = 9.96 CISPL = 27230.5 CP = 0.70307 CM = 0.91407

CB = 0.64265 CV = 0.00397 S = 5820. CS = 2.5589

S/LWL**2 = 0.16123100 FC + F1*DISPL/(LWL**3) =0.00006255

SLR	F	DISPL *	CP *	CM *	CB *	CV *	CCR	LCB *	F2
0.50	0.149	11578.	0.7362	0.3712	0.2732	0.C01688	0.4100	0.0039	0.000000
0.55	0.164	13095.	0.7315	0.4226	0.3091	0.001910	0.4100	0.0030	0.000000
0.60	0.179	14481.	0.7276	0.4697	0.3418	C.002111	0.4200	0.0024	0.361717
0.65	0.193	15721.	0.7244	0.5122	0.3710	C.002292	0.4800	0.0018	2.148273
0.70	0.208	16825.	0.7217	0.5502	0.3971	C.002453	0.5800	0.0014	4.555225
0.75	0.223	17803.	0.7195	0.584C	0.4202	0.002596	0.7500	0.0010	8.137231
0.80	0.238	18667.	0.7176	0.6139	C.4406	C.002722	0.9900	0.0007	12.625200
0.85	0.253	19431.	0.7161	0.6404	0.4586	0.002833	1.2700	0.0004	17.276640
0.90	0.268	20108.	0.7147	0.664C	0.4745	C.002932	1.7200	0.0002	24.576610
0.95	0.283	20707.	0.7136	0.6848	0.4887	C.003019	2.7400	0.0000	41.219280
1.C0	0.298	21239.	0.7126	0.7034	0.5012	C.003097	4.0200	-0.0001	60.702980
1.05	0.313	21713.	0.7117	0.7200	0.5124	C.003166	4.9000	-0.0003	72.241020
1.10	0.327	22136.	0.7110	0.7348	0.5224	0.C03227	5.0200	-0.0004	71.363980
1.15	0.342	22515.	0.7103	0.7480	0.5314	C.003282	4.8800	-0.0005	66.888440
1.20	0.357	22854.	0.7097	0.7600	0.5394	C.C03332	4.8800	-0.0006	64.913360

PREDICTED FORM DRAG COEFFICIENT = .338
FORM DRAG COEFFICIENT FROM MODEL TEST = .410

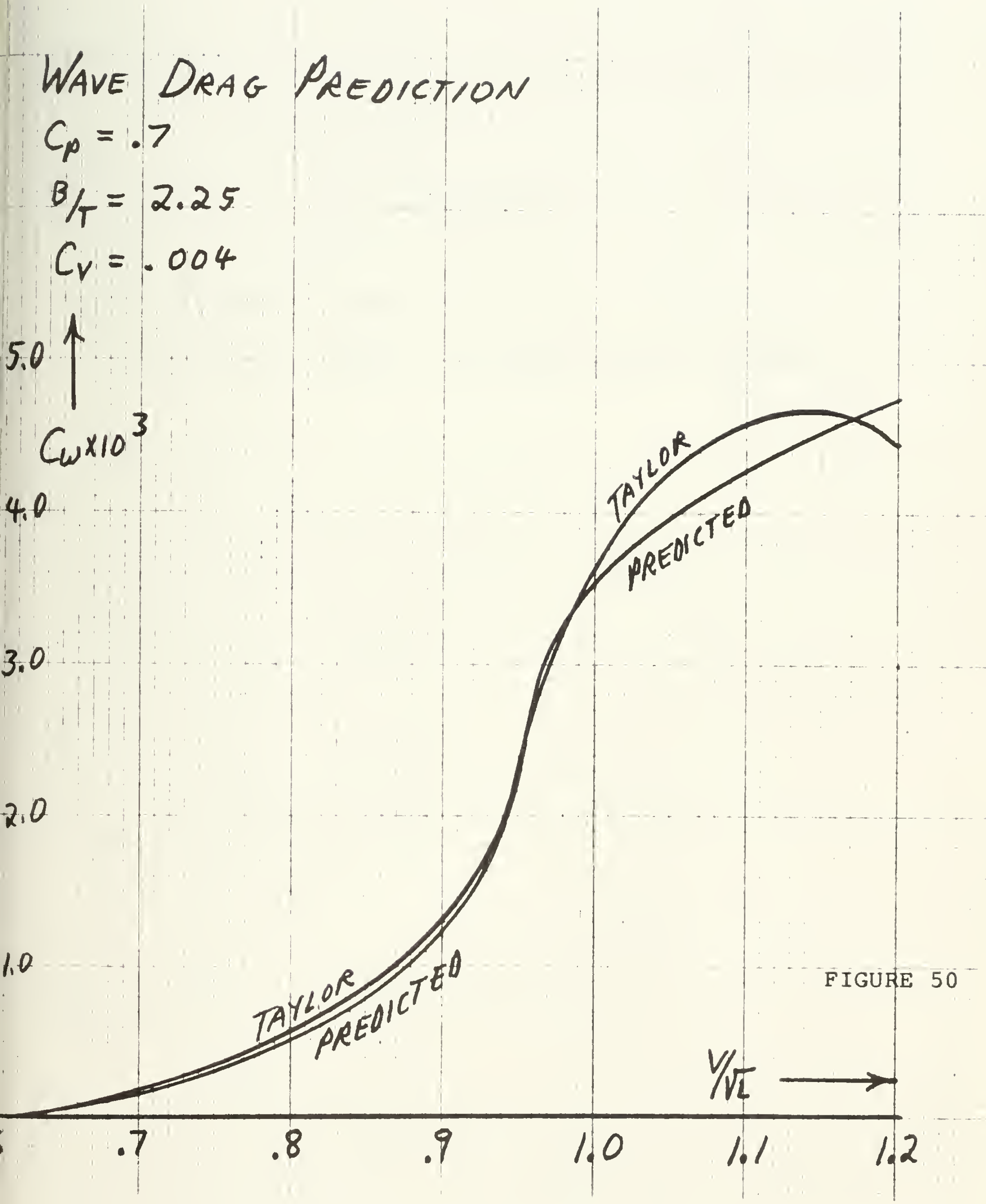

WAVE DRAG PREDICTION
$C_p = .7$
$B/T = 2.25$
$C_V = .004$
$C_W \times 10^3$
5.0
4.0
3.0
2.0
1.0
TAYLOR
PREDICTED
TAYLOR
PREDICTED
$V/\sqrt{L}$
.7
.8
.9
1.0
1.1
1.2

FIGURE 50

APPENDIX D

Samples of Wave and Form Drag Prediction for Vessels Unlike the Taylor Standard Series

"ANTIOPE" 5.5 METER YACHT [11]

SLR	F	DISPL *	CP *	CM *	CB *	CV *	CIRC M *	LCB *
0.5	0.149	38.	0.6150	0.0869	0.0534	0.002633	7.242	-0.0240
0.6	0.179	46.	0.5971	0.1091	0.0651	0.003209	6.780	-0.0231
0.7	0.208	53.	0.5832	0.1286	0.0750	0.003697	6.467	-0.0219
0.8	0.238	59.	0.5721	0.1455	0.0833	0.004102	6.247	-0.0211
0.9	0.268	64.	0.5629	0.1600	0.0900	0.004437	6.086	-0.0206
1.0	0.298	68.	0.5554	0.1722	0.0956	0.004713	5.965	-0.0202
1.1	0.327	71.	0.5492	0.1826	0.1003	0.004941	5.871	-0.0200
1.2	0.357	74.	0.5440	0.1914	0.1041	0.005131	5.798	-0.0199

LWL = 24.30 B = 6.27 T = 4.64 DISPL = 92.7 CP = 0.50918 CM

CB = 0.13113 CV = 0.00646 S = 160. CS = 3.3711

S/LWL**2 = 0.27096140 F0 + F1*DISPL/(LWL**3) =0.06884599

PREDICTED FORM DRAG COEFFICIENT. = .254

FORM DRAG COEFFICIENT FROM FULL SIZE TOWING TESTS = .450

PREDICTED FORM DRAG COEFFICIENT USING FAIR BODY B/T = .426

WAVE DRAG COEFFICIENT
PREDICTION FOR
5.5 METER YACHT "ANTIOPE" [11]

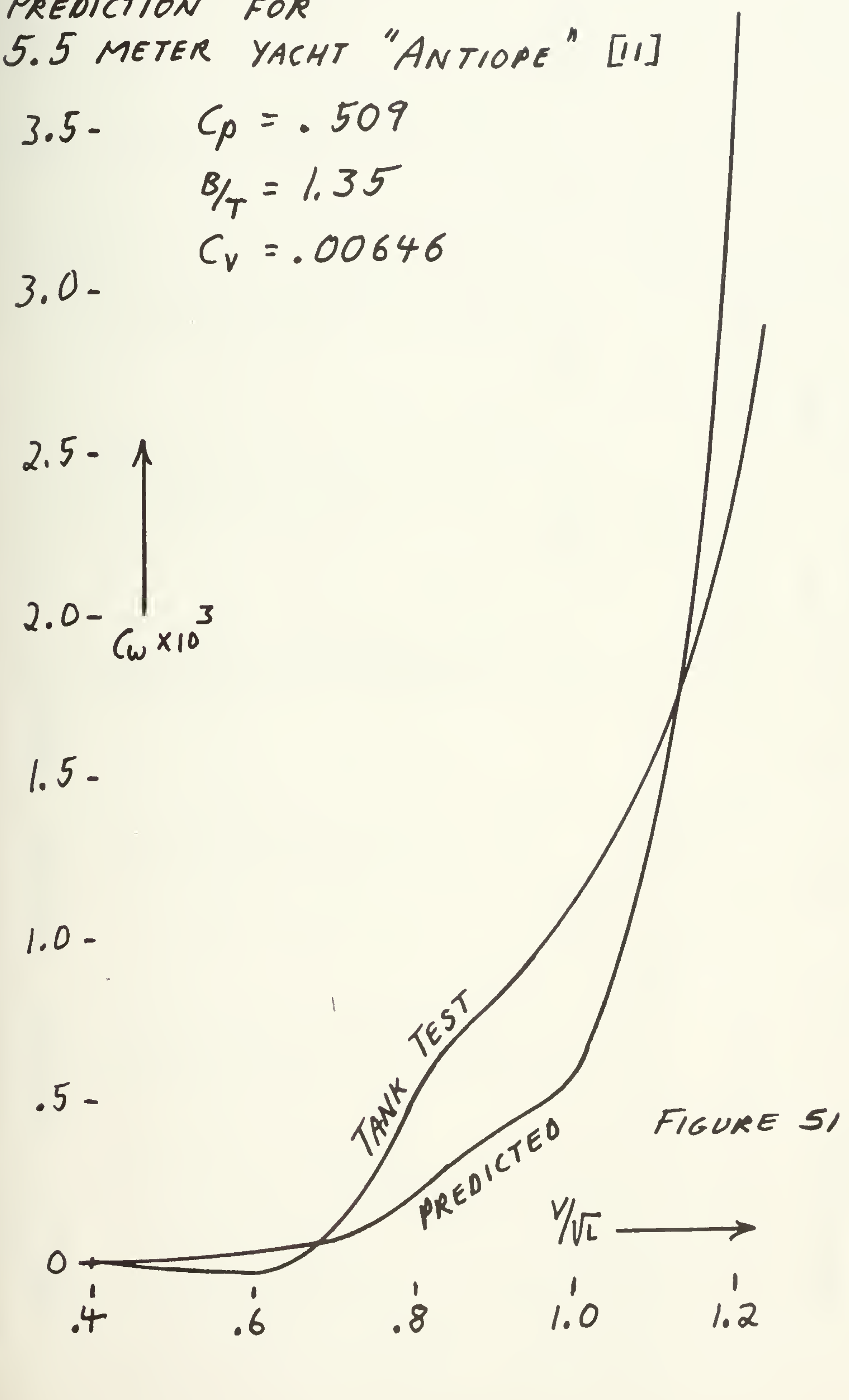


FIGURE 51

ROUND BOTTOM PATROL BOAT (EXPANDED RESISTANCE DATA SHEET # 77) [15]

SLR	F	DISPL *	CP *	CM *	CB *	CV *	CTPC M *	LCB *
0.5	0.143	1388.	0.6008	0.3486	0.2125	0.001388	8.965	0.0123
0.6	0.173	1622.	0.5986	0.4150	0.2484	0.001622	8.511	0.0093
0.7	0.203	1796.	0.5912	0.4652	0.2750	0.001796	8.227	0.0074
0.8	0.233	1925.	0.5861	0.5029	0.2948	0.001925	8.039	0.0061
0.9	0.263	2021.	0.5824	0.5315	0.3096	0.002021	7.909	0.0051
1.0	0.293	2095.	0.5798	0.5534	0.3209	0.002095	7.815	0.0045
1.1	0.327	2152.	0.5778	0.5705	0.3296	0.002152	7.745	0.0040
1.2	0.357	2198.	0.5763	0.5840	0.3266	0.002198	7.692	0.0036

LWL = 100.00 B = 14.84 T = 4.40 DISPL = 2460.1 CP = 0.56791 C

CR = 0.37675 CV = 0.00246 S = 1399. CS = 2.8206

S/LWL**2 = 0.13989990 F0 + F1*DISPL/(LWL**3) =0.05504801

PREDICTED FORM DRAG COEFFICIENT = .394

FORM DRAG COEFFICIENT FROM MODEL TEST = .491

WAVE DRAG COEFFICIENT PREDICTION
FOR ROUND BOTTOM PATROL BOAT [15]

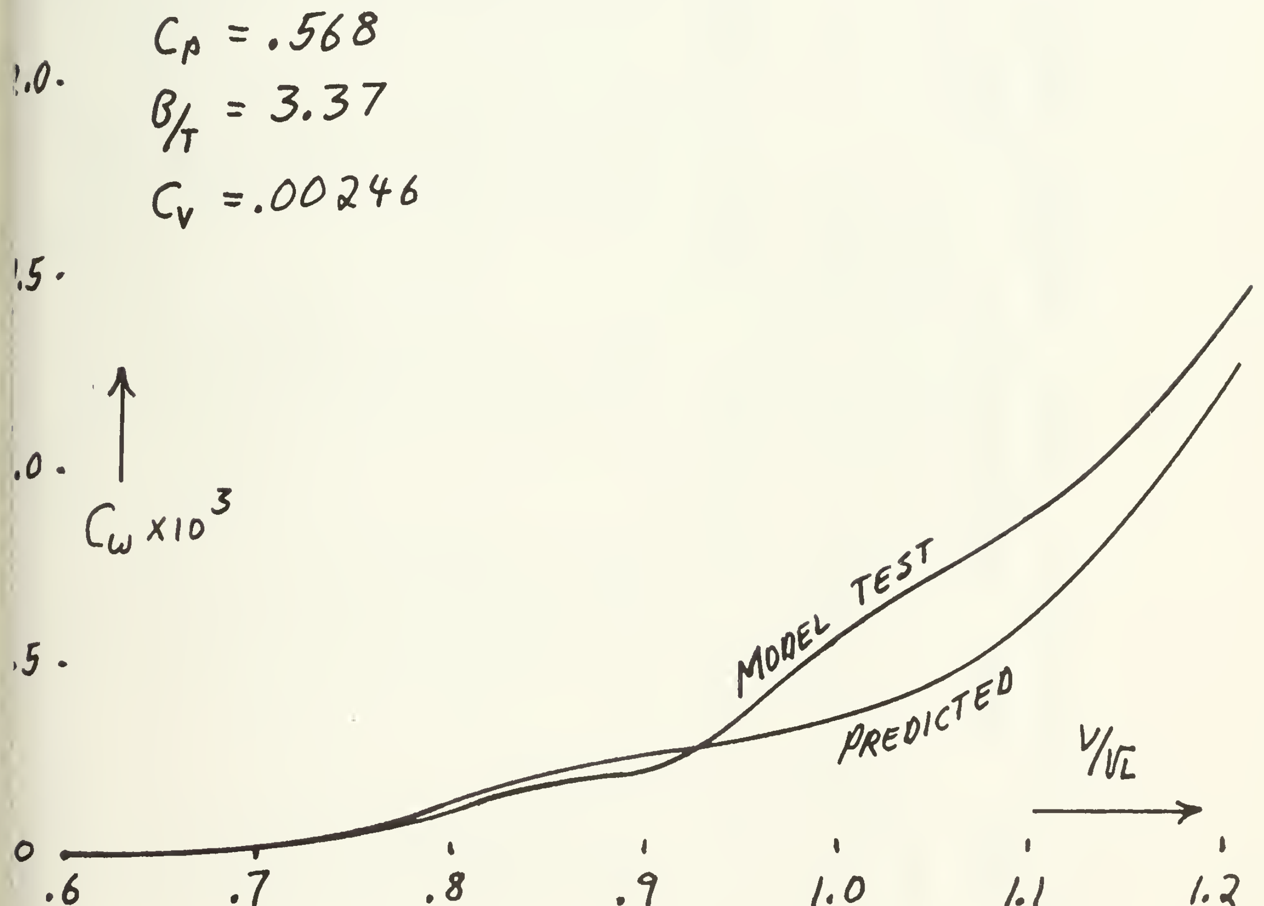


FIGURE 52

OLD DESTROYER WITH CRUISER STERN (EXPANDED RESISTANCE DATA SHEET # 119) [15]

SLR	F	DISPL *	CP *	CM *	CB *	CV *	CIRC M *	LCB *
0.5	0.149	55283.	0.6427	0.4591	0.2951	0.000864	10.500	0.0034
0.6	0.179	63242.	0.6387	0.5285	0.3375	0.000988	10.040	0.0026
0.7	0.208	68906.	0.6361	0.5781	0.3678	0.001077	9.757	0.0021
0.8	0.238	72994.	0.6344	0.6141	0.3896	0.001141	9.571	0.0017
0.9	0.268	76006.	0.6332	0.6407	0.4057	0.001188	9.443	0.0015
1.0	0.298	78272.	0.6323	0.6607	0.4177	0.001223	9.351	0.0013
1.1	0.327	80012.	0.6316	0.6761	0.4270	0.001250	9.283	0.0012
1.2	0.357	81373.	0.6311	0.6882	0.4343	0.001271	9.231	0.0011

LWL = 400.00   B = 39.10   T = 11.98   DISPL = 89108.1   CP = 0.62841   CM

CB = 0.47558   CV = 0.00139   S = 12312.   CS = 2.0622

S/LWL**2 = 0.07694395   F0 + F1*DISPL/(LWL**3) =0.03693372

PREDICTED FORM DRAG COEFFICIENT = .480

FORM DRAG COEFFICIENT FROM MODEL TEST = .440

WAVE DRAG COEFFICIENT PREDICTION
FOR OLD DESTROYER WITH CRUISER STERN
[15]

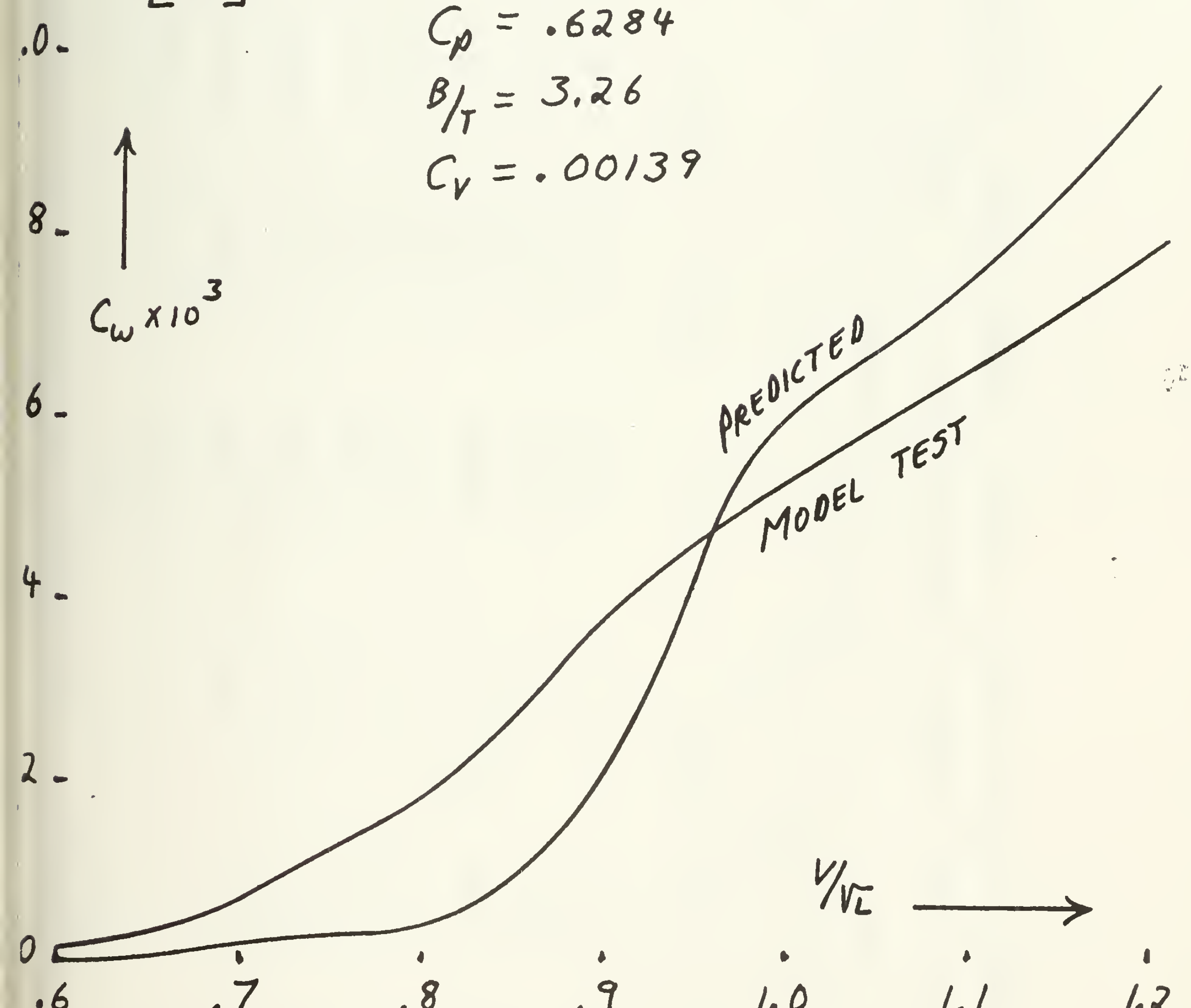


FIGURE 53

SURVEY LAUNCH (EXPANDED RESISTANCE DATA SHEET # 143) [15]

SLR	F	DISPL *	CP *	CM *	CB *	CV *	CIRC M *	LCB *
0.5	0.149	2102.	0.6424	0.3178	0.2042	0.002102	7.807	0.0253
0.6	0.179	2540.	0.6345	0.3889	0.2467	0.002540	7.329	0.0223
0.7	0.208	2881.	0.6291	0.4448	0.2798	0.002881	7.028	0.0205
0.8	0.238	3142.	0.6254	0.4880	0.3052	0.003142	6.827	0.0193
0.9	0.268	3343.	0.6228	0.5214	0.3247	0.003343	6.688	0.0186
1.0	0.298	3499.	0.6209	0.5474	0.3399	0.003499	6.587	0.0180
1.1	0.327	3622.	0.6194	0.5679	0.3518	0.003622	6.512	0.0177
1.2	0.357	3719.	0.6183	0.5842	0.3612	0.003719	6.454	0.0174

LWL = 100.00   B = 19.28   T = 5.34   DISPL = 4302.2   CP = 0.61232   CM

CB = 0.41787   CV = 0.00430   S = 2000.   CS = 3.0492

S/LWL**2 = 0.19999990   FO + F1*DISPL/(LWL**3) =0.10541720

PREDICTED FORM DRAG COEFFICIENT = .500

FORM DRAG COEFFICIENT FROM MODEL TEST = 2.54

WAVE DRAG COEFFICIENT PREDICTION
FOR A SURVEY LAUNCH [15]

$C_p = .61232$

$B/T = 3.61$

$C_v = .00430$

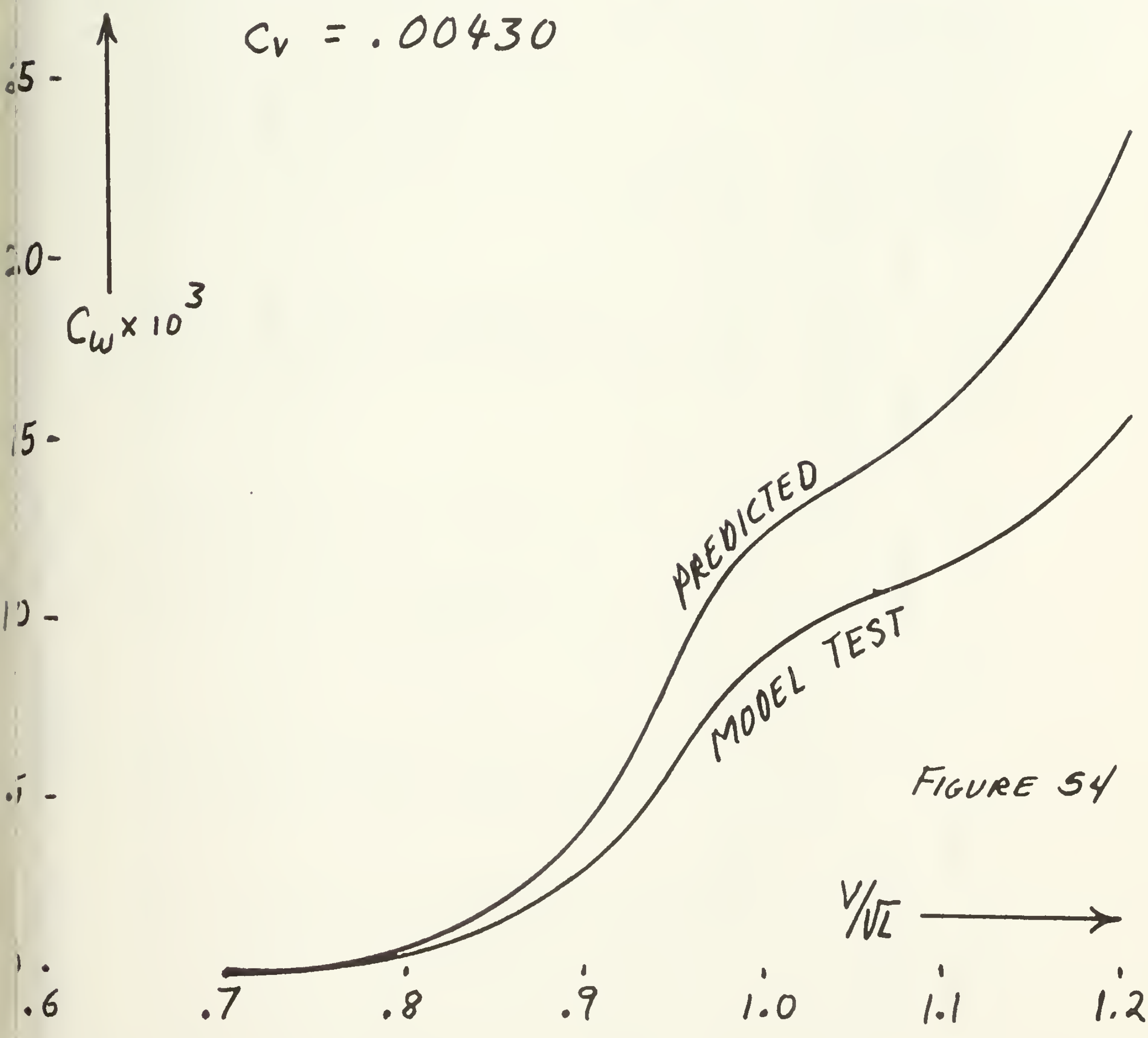


FIGURE 54

TRAWLER MODEL WQ (BSRA SERIES) [17]

SLP	F	DISPL *	CP *	CM *	CB *	CV *	CIRC M *	LCB *
0.5	0.149	10072.	0.6771	0.2765	0.1872	0.002369	7.501	-0.0000
0.6	0.179	13063.	0.6625	0.3665	0.2429	0.003072	6.879	0.0021
0.7	0.208	15677.	0.6523	0.4467	0.2914	0.003687	6.473	0.0036
0.8	0.238	17857.	0.6451	0.5145	0.3319	0.004200	6.198	0.0046
0.9	0.268	19633.	0.6401	0.5703	0.3650	0.004619	6.005	0.0053
1.0	0.298	21083.	0.6363	0.6159	0.3919	0.004959	5.864	0.0059
1.1	0.327	22257.	0.6335	0.6530	0.4137	0.005235	5.759	0.0063
1.2	0.357	23216.	0.6314	0.6835	0.4315	0.005461	5.679	0.0066

LWL = 152.00   B = 27.22   T = 12.20   DISPL = 29398.0   CP = 0.61989   CM

CB = 0.54646   CV = 0.00691   S = 5575.   CS = 2.5546

S/LWL**2 = 0.21242850   F0 + F1*DISPL/(LWL**3) =0.10113230

PREDICTED FORM DRAG COEFFICIENT = .476

FORM DRAG COEFFICIENT FROM MODEL TEST = 1.13

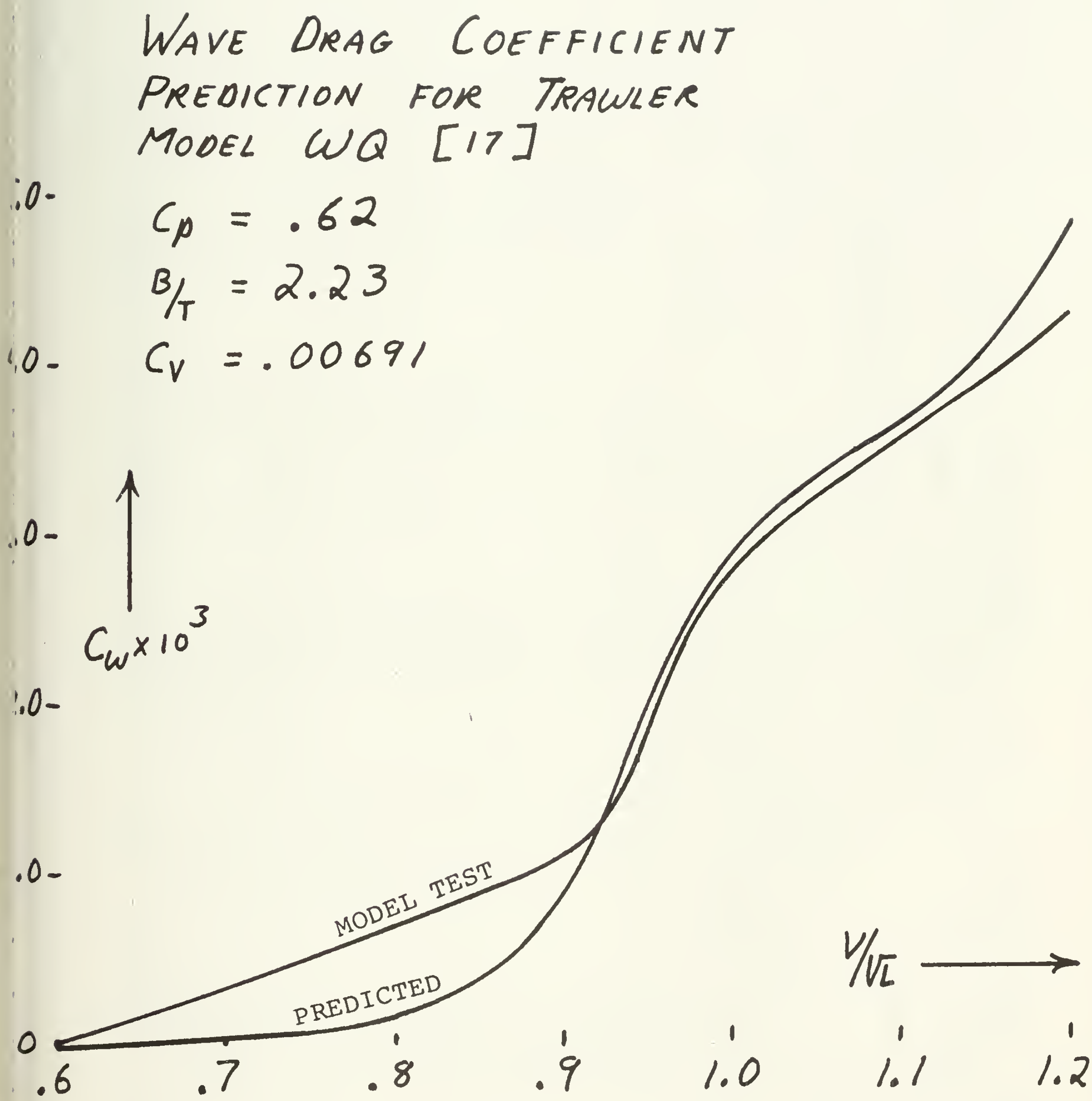

WAVE DRAG COEFFICIENT
PREDICTION FOR TRAWLER
MODEL WQ [17]
$C_p = .62$
$B/T = 2.23$
$C_V = .00691$
$C_W \times 10^3$
MODEL TEST
PREDICTED
$V/\sqrt{L}$
0
.6
.7
.8
.9
1.0
1.1
1.2

FIGURE 55

TRAWLER MODEL XF (BSRA SERIES) [17]

SLR	F	DISPL *	CP *	CM *	CB *	CV *	CIRC M *	LCB *
0.5	0.143	9303.	0.7015	0.2453	0.1721	0.002547	7.322	-0.0009
0.6	0.173	12270.	0.6857	0.3310	0.2270	0.003360	6.677	0.0014
0.7	0.208	14963.	0.6743	0.4105	0.2768	0.004096	6.250	0.0030
0.8	0.238	17263.	0.6661	0.4796	0.3195	0.004728	5.958	0.0042
0.9	0.268	19194.	0.6602	0.5379	0.3551	0.005255	5.752	0.0052
1.0	0.298	20783.	0.6559	0.5863	0.3845	0.005691	5.631	0.0057
1.1	0.327	22091.	0.6526	0.6263	0.4087	0.006049	5.488	0.0061
1.2	0.357	23169.	0.6501	0.6594	0.4287	0.006344	5.402	0.0065

LWL = 154.00 B = 26.33 T = 13.33 DISPL = 30330.2 CP = 0.63655 CM

CB = 0.56114 CV = 0.00839 S = 5479. CS = 2.5352

S/LWL**2 = 0.23103330 FO + F1*DISPL/(LWL**3) =0.10549090

PREDICTED FORM DRAG COEFFICIENT = .457

FORM DRAG COEFFICIENT FROM MODEL TEST = 1.25

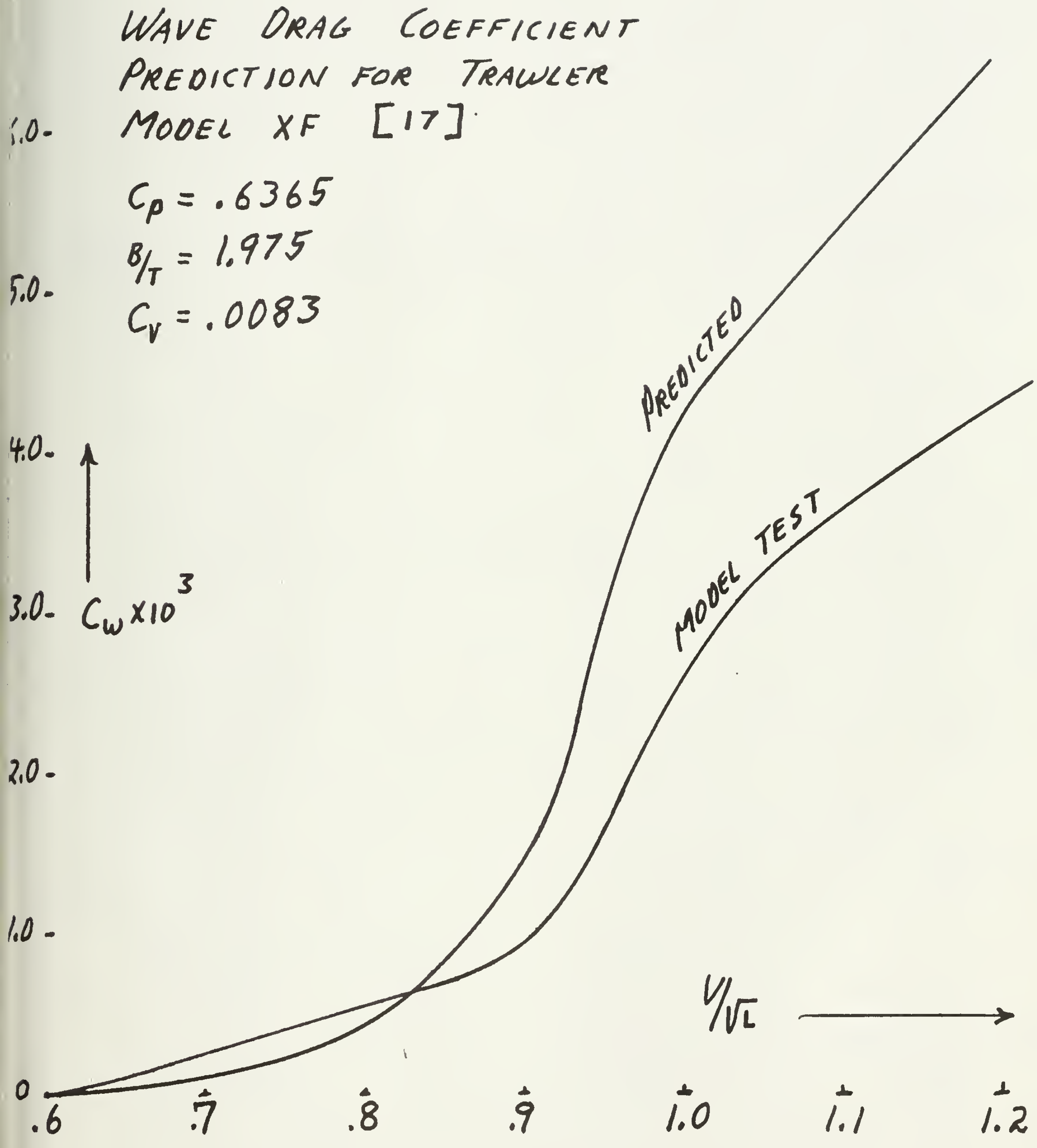

WAVE DRAG COEFFICIENT
PREDICTION FOR TRAWLER
MODEL XF [17]
C_p = .6365
B/T = 1.975
C_V = .0083
PREDICTED
MODEL TEST
$C_W \times 10^3$
V/√L
0
1.0
2.0
3.0
4.0
5.0
.6
.7
.8
.9
1.0
1.1
1.2

FIGURE 56